Management Planning Program 2017 - 18 Year-End Report

April 1, 2017 – March 31, 2018

BRITISH COLUMBIA
BC Parks

June 2018

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Report Summary

General Information

- 71.7% of protected areas have approved management plans, which is an increase of 0.5% from the 2016/17 Final Report.

- Seven draft management plans were approved for posting to the BC Parks website for public feedback during the reporting period:
  - Bridge Lake Park;
  - Lac du Bois Grasslands Protected Area;
  - Mara Meadows Park;
  - Mount Minto/K'iyan Conservancy;
  - Six Mile Hill Protected Area;
  - Skihist Park; and
  - Thunderbird's Nest (*T'iitsk'in Paawats*) Protected Area

- Eight management plans were approved during the reporting period:
  - Management plans for four Lillooet Land and Resource Management Plan Goal 2 areas with important natural features: Bridge River, Fred Antoine, Gwyneth Lake and Yalakom parks;
  - Management plans for the adjoining Carp Lake Park and Mackinnon Esker Ecological Reserve;
  - A management plan for Syringa Park in the Kootenays which replaces the 1999 Management Direction Statement; and
  - A management plan for Wakes Cove Park, located on Valdes Island, southeast of Nanaimo, which replaces the 2003 Purpose Statement and Zoning Plan.

Performance Measures:

- The 2017/18 performance measure targets were to post draft management plans for public review for 20 areas[1] and complete final management plans for 21 areas.
- In total, seven draft management plans were released for public review (35% of target) and 8 final management plans were approved (38% of target).
- In addition to the 8 management plans approved, management plans for Bridge Lake Park, Skihist Park and Thunderbird's Nest (*T'iitsk'in Paawats*) Protected Area had been submitted by March 31, 2018, for approval. The management plans are expected to be approved early in the 2018/19 reporting period.

[1] The original performance management target respecting posting draft management plans for public review was 19. Northern Region – Skeena subsequently increased its target by 1.

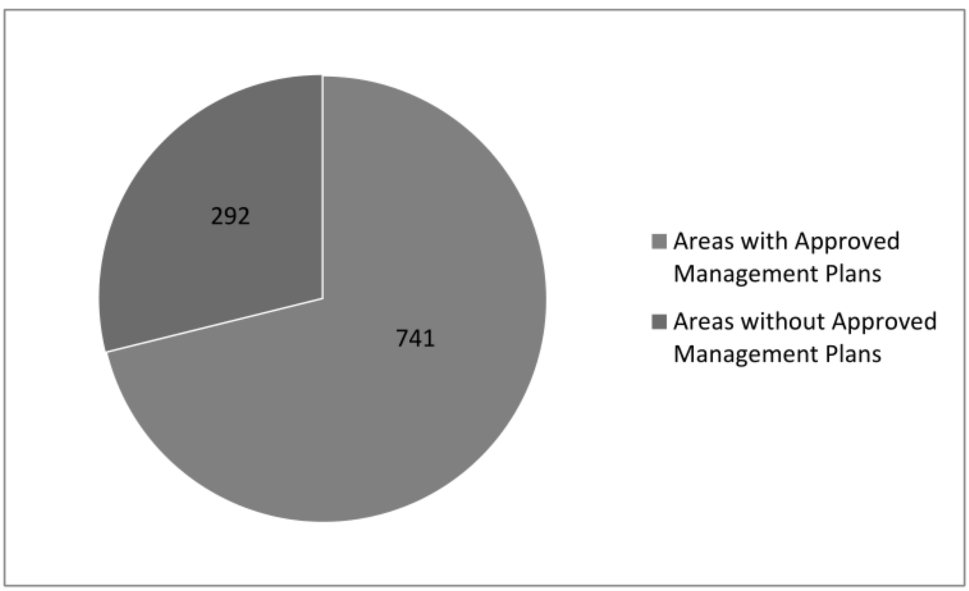
Approved Management Plans[1]

Provincial Summary

- The *Strategic Management Planning Policy for Ecological Reserves, Parks, Conservancies, Protected Areas and Recreation Areas* requires that a management plan be prepared and kept current for every protected area in the BC Parks' system. This performance measure (% of protected areas with approved management plans) is tracked in the BC Parks Annual Report and in the two management plan program reports at the end of the second and fourth quarters.

- Eight management plans were approved in 2017/18: a management plan for Syringa Park in the Kootenays which replaces the existing approved Management Direction Statement; four management plans for Lillooet Land and Resource Management Plan Goal 2 areas with important natural features (Bridge River, Fred Antoine, Gwyneth Lake and Yalakom parks); management plans for the adjoining Carp Lake Park and Mackinnon Esker Ecological Reserve; and a management plan for Wakes Cove Park located on Valdes Island, southeast of Nanaimo which replaces the existing Purpose Statement and Zoning Plan.

- 71.7% of protected areas have approved management plans, which is an increase of 0.5% from the 2016/17 Final Report[2].



[1] For the purposes of this report, the term 'approved management plan' refers to the various types of documents that are being used to provide valid management direction for a given protected area (e.g., master plans, management direction statements, purpose statements and management plans). A document is considered 'valid' only if it continues to provide adequate strategic direction and guidance for operational activities in the protected area. Plan validity will be assessed on a regular and ongoing basis and numbers will fluctuate accordingly.

[2] The management plans for Syringa and Wakes Cove parks did not increase the number of approved management plans as they replace an existing Management Direction Statement and Purpose Statement and Zoning Plan respectively which were previously included in the count.

By Designation

- 82% of parks have approved management plans, representing 82% of the area within this designation (by hectares).
- While only 19% of conservancies have approved management plans, 32% of the area (by hectares) within this designation has a valid management plan.
- Nearly 90% of ecological reserves have approved management plans, representing 98% of the area within this designation (by hectares).
- The two recreation areas both have approved management plans.
- Almost 60% of the areas established under the *Environment and Land Use Act* (ELUA) have approved management plans, representing roughly half of the area within this designation.

Overview of Approved Management Plans (by Designation Type)

Designation Type	Total # of protected areas	Total # of protected areas with approved MP	MPs approved since March 2017	% of protected areas (#) with approved MP	% of protected land (ha) with approved MP
Conservancies	**156**	**30**	**0**	**19.2%**	**32%**
Environment and Land Use Act (ELUA) Designations	**84**	**50**	**0**	**59.5%**	**53%**
Ecological Reserves	**148**	**133**	**+1**	**89.9%**	**98%**
Parks	**643**	**527**	**+7**	**82%**	**82%**
Class A	628	523	+7	83.3%	82%
Class B	2	2	0	100%	100%
Class C	13	2	0	15.4%	5%
Recreation Areas	**2**	**2**	**0**	**100.0%**	**100%**
All Protected Areas	**1033**	**741**	**+8**	**71.7%**	**71%**

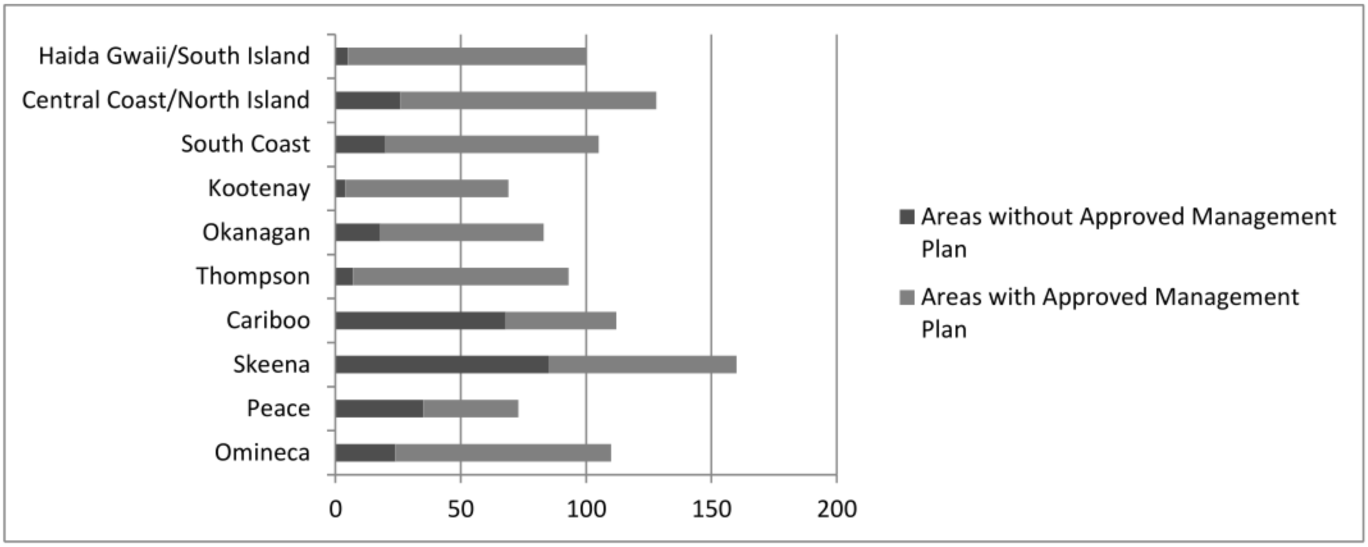
By Region and Section

- In the Northern Region, 58% of protected areas have approved management plans, covering 66% of the area dedicated to protected areas. 78% of the protected areas in the Omineca Section have approved management plans, representing 96% of the protected area land base. Comparatively, 52% and 47% of the protected areas have approved management plans in the Peace Section and Skeena Section, representing 20% and 72% respectively of the area dedicated to protected areas in these sections.
- 92% of protected areas, representing 93% of the protected land base, have approved management plans in the Thompson Section. Comparatively, 39% of the protected areas in the Cariboo Section have approved management plans, representing 42% of the area dedicated to protected areas.
- 86% of protected areas covering over 90% of the protected land base have approved management plans across the Kootenay Okanagan Region. 94% of the protected areas in the Kootenay Section have approved management plans, covering 99% of the protected land base. In the Okanagan Section, 78% of the protected areas have approved management plans, covering 75% of the protected land base.
- 81% of protected areas in the South Coast Region have approved management plans, covering 86% of the area dedicated to protected areas in the region.
- 86% of the protected areas in West Coast Region have approved management plans, representing 90% of the area dedicated to protected areas in this region.

Overview of Approved Management Plans (by Region/Section)

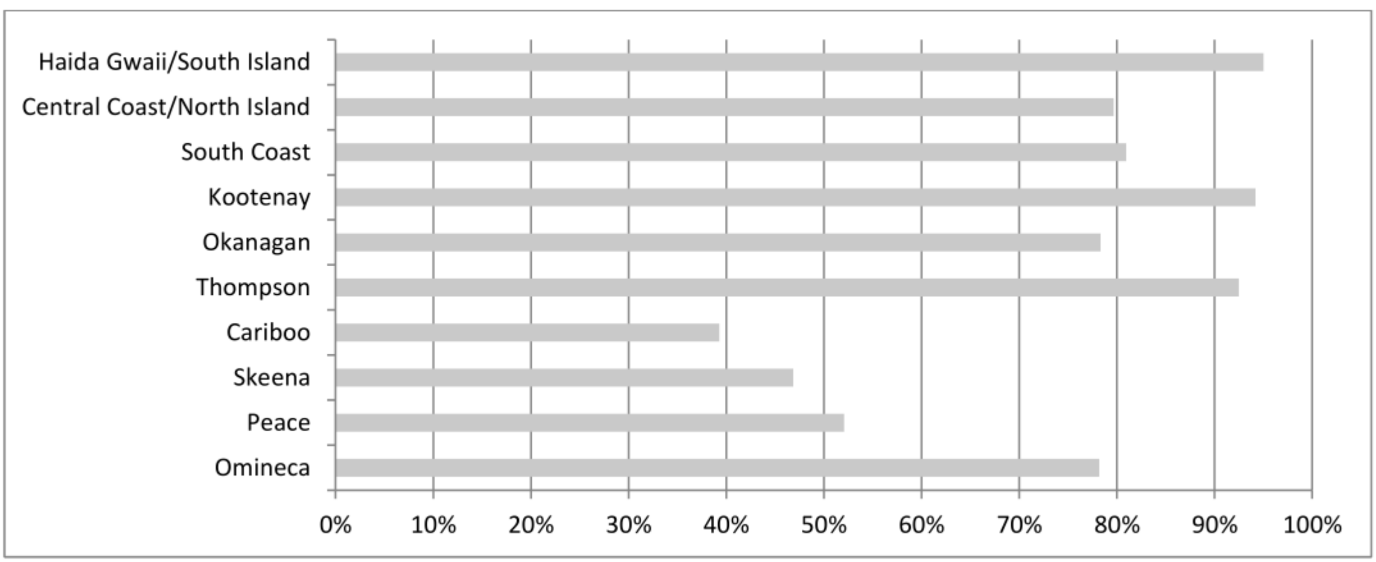
Region/Section	Total # of protected areas (PAs)	Total # of PAs with approved MP	MPs Approved since March 2017	% of PAs (#) with approved MP	Total area (ha) protected	% of protected land (ha) with approved MP
Northern Region	**343**	**199**	**+2**	**58%**	8,822,928	**66%**
Omineca	110	86	+2	78%	2,251,806	96%
Peace	73	38	0	52%	1,918,614	20%
Skeena	160	75	0	47%	4,652,509	72%
Thompson Cariboo Region	**205**	**130**	**+4**	**63%**	2,517,220	**63%**
Cariboo	112	44	0	39%	1,444,029	42%
Thompson	93	86	+4	92%	1,073,192	93%
Kootenay Okanagan Region	**152**	**130**	**+1**	**86%**	959,378	**90%**
Okanagan	83	65	0	78%	333,626	75%
Kootenay	69	65	+1	94%	625,752	99%
South Coast Region	**105**	**85**	**0**	**81%**	565,466	**86%**
West Coast Region	**228**	**198**	**+1**	**87%**	1,204,889	**90%**
Central Coast/North Island	128	102	0	80%	667,897	**82%**
Haida Gwaii/South Island	100	96	+1	96%	536,992	**99.9%**

Protected Areas with an Approved Management Plan (by Section)



# of Protected Areas with Approved Management Plan

Percentage of Protected Areas with an Approved Management Plan (by Section)



% of Protected Areas with Approved Management Plan

Management Planning Projects

Project Progress

Two of the management plan project stages have been chosen as performance measures and are reported on at the end of the second and fourth quarters. These two stages are:

- number of draft management plans released for public review; and
- number of final management plans approved.

In April 2017, as part of the annual work plan, Planning Section Heads submitted their targets for these two measures. The targets were then approved and supported by the Regional Directors. The 2017/18 targets were to release 20 draft management plans for public review and complete through the approval process 21 final management plans.

During 2017/18:

- seven areas had draft management plans released to the public (35% of target); and
- eight areas had final management plans approved (38% of target).

Project Progress Overall

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed in fiscal 2017/18 by #	Completed in fiscal 2017/18 by % of target
Areas with Draft Management Plans Released to the Public	20[3]	7	35%
Areas with Final Management Plans Approved	21	8	38%

At present, 71.7% of protected areas have approved management direction which is an increase of 0.5% from the previous year. Increased success in addressing the recurring issues and challenges to completing management plans will need to be achieved and sustained over a number of years if the strategic management planning policy goal of having an approved management plan in place for every protected area is ever to be realized.

[3] The original performance management target respecting posting draft management plans for public review was 19. Northern Region – Skeena subsequently increased its target by 1.

Performance Measure by Section – Draft Management Plans Released to Public

Regional Section	Target for 2017/18 Fiscal (as set in April 2017)	Completed to-date (as of March 31, 2018) by #	Completed to-date (as of March 31, 2018) by % of target
Kootenay	0	0	N/A
Okanagan	1	1	100%
Omineca	0	0	N/A
Skeena	5	1	20%
Peace	3	0	0%
South Coast	1	0	0%
Thompson	4	3	75%
Cariboo	5	1	20%
West Coast	1	1	100%

Performance Measure by Section – Final Management Plans Approved

Regional Section	Target for 2017/18 Fiscal (as set in April 2017)	Completed to-date (as of March 31, 2018) by #	Completed to-date (as of March 31, 2018) by % of target
Kootenay	1	1	100%
Okanagan	0	0	N/A
Omineca	2	2	100%
Skeena	7	0	0%
Peace	0	0	N/A
South Coast	0	0	N/A
Thompson	6	4	67%
Cariboo	1	0	0%
West Coast	4	1[4]	25%

[4] Two plans were "re-approved" (Dzawadi/Klinaklini Estuary Conservancy and Wahkash Point Conservancy) in June 2017. They had been approved by the Executive Director previously, but when the signatory First Nations made changes to the documents, re-approval was necessary. While they have received Executive Director approval, the project is not considered complete until the final signatures have been secured from the participating First Nations (this is the same situation for the Kt'ii Racey Conservancy in the Cariboo).

Regional Details

Kootenay Okanagan Region

Workplan Summary

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed To-date (as of March 31, 2018)
Draft Management Plan Released to the Public	1	1
Final Management Plan Approved	1	1

Workplan Details

Protected Area	Section	2017/18 Workplan Target (**Red** indicates target has not been achieved for 2017/18, **Green** indicates the target has been achieved this fiscal)			Comments
		Initiate Plan	Complete Draft Plan for Public Review	Complete Final Plan	
Syringa Park	Kootenay			X	ED approved management plan April 2017.
Mara Meadows Park	Okanagan		X		Draft plan posted for public review.
Kalamalka Lake Park	Okanagan	X			Draft plan developed in winter 2018, with final plan roll-out in spring 2018.

South Coast Region

Workplan Summary

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed To-date (as of March 31, 2018)
Draft Management Plan Released to the Public	1	0
Final Management Plan Approved	0	0

Workplan Details

		2017/18 Workplan Target (**Red** indicates target has not been achieved for 2017/18, **Green** indicates the target has been achieved this fiscal)			
Protected Area	**Section**	**Initiate Plan**	**Complete Draft Plan for Public Review**	**Complete Final Plan**	**Comments**
Pinecone Burke Park	South Coast		X		Progress is being made on the plan.
Nlhaxten/Cerise Creek Conservancy	South Coast	X			Project initiated, funded and led by Lil'wat First Nation. Has undergone HQ reviews from Planning, Conservation, Recreation and Indigenous Relations sections.

West Coast Region

Workplan Summary

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed To-date (as of March 31, 2018)
Draft Management Plan Released to the Public	1	1
Final Management Plan Approved	4	1

Workplan Details

Protected Area	Section	2017/18 Workplan Target (**Red** indicates target has not been achieved for 2017/18, **Green** indicates the target has been achieved this fiscal)			Comments
		Initiate Plan	Complete Draft Plan for Public Review	Complete Final Plan	
Thunderbird's Nest (T'iitsk'in Paawats) Protected Area	West Coast		X		Draft management plan posted in January and final plan approved in April 2018 – will be reflected in next report.
Dzawadi/Klinaklini Estuary Conservancy	West Coast			X	Final plan completed, re-approved by ED. Discussion underway with First Nation to set a date for a signing ceremony.
Wahkash Point Conservancy	West Coast			X	Final plan completed, re-approved by ED. Discussion underway with First Nation to set a date for a signing ceremony.
Wakes Cove Park	West Coast			X	Approved by ED October 5, 2017.
Mount Geoffrey Escarpment Park	West Coast			X	Draft plan released for public review in 2016/17. Coordinating with regional district (adjacent park planning) on next steps in 2018 and moving forward with final reviews in 2018/19.

Thompson Cariboo Region

Workplan Summary

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed To-date (as of March 31, 2018)
Draft Management Plan Released to the Public	9	4
Final Management Plan Approved	7	4

Workplan Details

Protected Area	Section	2017/18 Workplan Target (**Red** indicates target has not been achieved for 2017/18, **Green** indicates the target has been achieved this fiscal)			Comments
		Initiate Plan	Complete Draft Plan for Public Review	Complete Final Plan	
Fiordland Conservancy	Cariboo		X		Draft plan wording underwent a series of revisions, but good progress made to release for public comment in early 2018/19.
Kt'ii/Racey Conservancy	Cariboo			X	Final plan approved by ED, RD and one FN in 2016/17, but awaiting one final FN to signoff.
Pooley Conservancy	Cariboo		X		Draft plan wording underwent a series of revisions, but good progress made to release for public comment in early 2018/19.
Kluskoil Lake Park	Cariboo		X		Draft plan not completed.
Titetown Park	Cariboo		X		Draft plan not completed.
Bridge Lake Park	Cariboo		X		Draft plan posted to website for public comment.
Schoolhouse Park	Cariboo	X			Initiation of plan not completed.
South Chilcotin Mountains Park	Thompson			X	Submitted to ED for final review, but sent back for revisions – expect completion in 2018/19.
Big Creek Park	Thompson			X	Submitted to ED for final review, but sent back for revisions – expect completion in 2018/19.
Gwyneth Lake Park	Thompson			X	ED approved management plan April 2017.
Fred Antoine Park	Thompson			X	ED approved management plan April 2017.
Yalakom Park	Thompson			X	ED approved management plan April 2017.
Bridge River Delta Park	Thompson			X	ED approved management plan April 2017.
Skihist Park	Thompson		X		Draft plan posted to website for public comment.
Marble Canyon Park	Thompson	X			Planning process on hold.

French Bar Park	Thompson		x		Draft plan not completed.
Lac du Bois Grasslands Protected Area	Thompson		x		Draft plan posted to website for public comment.
Six Mile Hill Protected Area	Thompson		x		Draft plan posted to website for public comment.

Northern Region

Workplan Summary

Performance Measure	Target for 2017/18 Fiscal (as set in April 2017)	Completed To-date (as of March 31. 2018)
Draft Management Plan Released to the Public	8	1
Final Management Plan Approved	9	2

Workplan Details

Protected Area	Section	2017/18 Workplan Target (**Red** indicates target has not been achieved for 2017/18, **Green** indicates the target has been achieved this fiscal)			Comments
		Initiate Plan	Complete Draft Plan for Public Review	Complete Final Plan	
Carp Lake Park	Omineca			X	ED approved management plan April 2017.
Mackinnon Esker Ecological Reserve	Omineca			X	ED approved management plan April 2017.
Northern Rocky Mountains Park	Peace		X		
Northern Rocky Mountains Protected Area	Peace		X		
Redfern-Keily Park	Peace		X		
Bishop Bay-Monkey Beach Conservancy	Skeena			X	Joint plan with Bishop Bay-Monkey Beach Corridor Conservancy. Undergoing final re-draft as per HQ review.
Bishop Bay-Monkey Beach Corridor Conservancy	Skeena			X	Joint plan with Bishop Bay-Monkey Beach Conservancy. Undergoing final re-draft as per HQ review.
Hanna Tintina Conservancy	Skeena		X		Draft plan not completed.
K'ootz/Khutze Conservancy	Skeena		X		
Ksgaxl/Stephens Island Conservancy	Skeena		X		Presence of cabins in Skiakl Bay is an outstanding item. FN and BC Parks have a general approach for confirmation. Once the cabins are dealt with, a public outreach will occur on the draft plan.
Lucy Islands Conservancy	Skeena		X		Review to occur concurrently with Ksgaxl/Stephens Island Conservancy.

Manzanita Cove Conservancy	Skeena			x	In consultation with FN to finalise four plans concurrently.
Mount Minto/K'iyan Conservancy[5]	Skeena		x		Draft plan approved for posting to website for public comment.
Thulme Falls Conservancy	Skeena			x	In consultation with FN to finalise four plans concurrently.
Tutshi Lake/T'ooch' Aayi Conservancy	Skeena			x	Final plan pending – signed by BC Parks HQ. s.13;s.16 s.13;s.16
Wales Harbour Conservancy	Skeena			x	In consultation with FN to finalise four plans concurrently.
Zumtela Bay Conservancy	Skeena			x	In consultation with FN to finalise four plans concurrently.
Alty Conservancy	Skeena	x			Initial project plan posted to BC Parks website to gather public input to initiate drafting process.
K'waal Conservancy	Skeena	x			Initial project plan posted to BC Parks website to gather public input to initiate drafting process.

[5] The Mount Minto/K'iyan Conservancy was not on the management plan projections list for 2017/18, however stalled plans can become re-activated periodically for a variety of reasons.

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Withheld pursuant to/removed as

DUPLICATE

Permit: 01152

April 16, 2018

To: **Cariboo Pulp and Paper**

Re: **Split Sampling Audit Summary Report**

Dear: Pat Hagerty,

Thank you for participating in the Split Sampling Program. Environmental data produced under order or enactment such as those required by permit provide critical information upon which crucial decisions are made regarding environmental protection. For this reason it is incumbent upon the Province to ensure that environmental data is produced with a reliable level of quality. The Split Sampling Program is a robust audit mechanism that evaluates and monitors that quality by comparing the analytical results of your samples to those obtained by a Ministry representative.

The Split Sampling Program is a Quality Assurance Program administered by the Ministry of Environment and Climate Change Strategy. Evaluations of the Split Sample test results are conducted by the Ministry's Laboratory Standards and Quality Assurance Unit (LSQA). Since your last audit the LSQA unit has simplified the evaluation process through a revision of the Split Sampling Program which is reflected in this summary report.

Performance Evaluations

Split Sample audits are used to conduct an assessment of a permittee's sampling performance and a laboratory's analytical performance. Where possible a sample splitter is used to produce homogenous aliquots of sample material from a known source thereby reducing to the greatest degree possible, the potential impacts of media heterogeneity. The removal of this potential interference allows an evaluation to distinguish and report on the remaining aspects of producing representative environmental parameters. These remaining aspects include field QA/QC, sample handling, processing, preservation, shipping, laboratory processing and sample handling, laboratory equipment and instrumentation, QA/QC, and reporting.

Audit Definition and Performance Criteria

Each submission of split samples constitutes an *audit*. Audit testing is divided into Water Chemistry, toxicity and Microbiological components although not all submissions include toxicity and or microbiological testing. Water chemistry results are evaluated via a statistical comparison of the permittee's laboratory results with the Ministry's laboratory results. An evaluation of microbiological test results are scored according to the grading scale developed for

the CMPT data assessment protocol. Toxicity test results are scored by absolute deviation. The maximum allowable deviation for a toxicity test is 31%.

Two criterion are applied to each audit; a *Percent of Failed Tests* with a 25% threshold and an overall *Performance Evaluation* which must achieve 70%. Each test result produces a statistical performance score of 5, 4, 2 or 0 *points* where 5 is the highest score and both 2 and 0 indicate an unacceptable (failed) test result. The average of all performance scores produced in a single audit constitutes the overall Performance Evaluation. Evaluations that result in a percentage of Failed Tests below 25 and a Performance Evaluation equal to or greater than 70% constitutes an audit pass.

2018 Audit Summary

During this audit it was determined that the analytical results for Biological Oxygen Demand (BOD), Dehydroabietic Acid, and Isopimaric & Paulstric Acid did not fall within the Acceptable Deviation range. The deviation factors for all three tests range from 1.1 to 1.75 and are not considered to be substantial discrepencies. Your sample submission required dilution for several acid parameter tests. Dilutions result in an increase in the *Lowest Detection Limit* for the affected tests and as such create a discrepancy with the evaluation process and may have been a factor in the two failed acid tests. Please consult with your laboratory to establish the reason for the dilution.

A summary of your test results are presented in the following table:

Client Name:	Cariboo Pulp & Paper
Audit No:	18.1
Requisition No.:	S1519841999
Sample Date:	6-Mar-18
Total Tests Included:	25
Total Points Assigned:	107
Failed Test Results:	3
Percent of Failed Tests:	12%
Performance Evaluation:	86%
Audit Result:	PASS

For more information on the calculation of the performance score rating or any other information regarding the Split Sampling Program, please feel free to contact me. For any permit related question please contact your Environmental Protection Officer.

Blair R Irwin, P.Ag., EP, B.Sc.,
Senior Quality Management Analyst
Phone: 250-387-9455
Email: Blair.Irwin@gov.bc.ca

cc: Jack Green

SPLIT SAMPLING QUALITY ASSURANCE PROGRAM - AUDIT REPORT

Permit Number: PE01152
Client Name: Cariboo Pulp & Paper
Regional Office: Williams Lake
EPD officer: Jack Green

Date of Last Amendment: 13-Apr-18
Amended by: BRI

Ensure that the 'functions' are set in each of the newly actived cells within the evaluation block of the spreadsheet.

Manual Data Entry Block											Automated Evaluation Block				
Audit No.	Requisition No.	Sample Site ID	Sample Location/ Site Name	Sample Date	Sample Type	Parameter	Units	MOE LDL	Permit Results	MOE Results	Absolute Deviation	Acceptable Deviation	Deviation Factor	Points Assigned	Pass/ Flag
Physical Tests						**Colour**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Color	Col. Units	50	500	NR	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Color	Col. Units	50	1230	835	395.0	188.8	2.1	0	Fail
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Color	Col. Units	10	780	740	40.0	118.8	0.3	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Color	Col. Units	5	949	964	15.0	143.4	0.1	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	06-Mar-18	WW	Color	Col. Units	25	834	867	33.0	158.0	0.2	5	Pass
Physical Tests						**pH**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	pH	pH Units	0.5	8.3	8.2	0.1	1.9	0.0	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	pH	pH Units	0.5	8.0	8.0	0.0	1.8	0.0	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	pH	pH Units	0.10	7.60	8.00	0.4	1.3	0.3	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	pH	pH Units	0.10	7.82	8.17	0.4	1.3	0.3	5	Pass
18.1	S1519845984	E103117	Cariboo Pulp and Paper	06-Mar-18	WW	pH	pH Units	0.10	7.70	7.94	0.2	1.3	0.2	5	Pass
Physical Tests						**Conductivity**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Specific Conductance	mS/cm	1.0	2000	NR	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Specific Conductance	mS/cm	1.0	1860	1782	78.0	505.4	0.2	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Specific Conductance	mS/cm	2.0	2027	2010	17.0	571.3	0.0	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Specific Conductance	mS/cm	2.0	2360	2340	20.0	664.7	0.0	5	Pass
18.1	S1519845984	E103117	Cariboo Pulp and Paper	06-Mar-18	WW	Specific Conductance	mS/cm	2.0	1969	1970	1.0	560.0	0.0	5	Pass
Physical Tests						**Volatile Suspended Solids (aka Residue Nonfilterable - Volatile)**									
	S15000975	E103117	Cariboo Pulp and Paper	11.06.01	WW	Residue Nonfilterable- Volatile	mg/L	1.0	18	17	1.0	6.2	0.2	5	Pass
	S1325876469	E103117	Cariboo Pulp and Paper	12.01.09	WW	Residue Nonfilterable- Volatile	mg/L	1.0	29	30	1.0	9.9	0.1	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Volatile Suspended Solids (VSS)	mg/L	3.0	23.0	20.6	2.4	10.1	0.2	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Volatile Suspended Solids (VSS)	mg/L	4.5	22.3	15.9	6.4	10.9	0.6	4	Pass
18.1	S1519845984	E103117	Cariboo Pulp and Paper	06-Mar-18	WW	Volatile Suspended Solids (VSS)	mg/L	3.0	32.5	29.4	3.1	12.6	0.2	5	Pass
Physical Tests						**Total Suspended Solids (aka Residue Nonfilterable)**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Residue Nonfilterable	mg/L	4.0	24	NR	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Residue Nonfilterable	mg/L	4.0	29	31	1.5	14.3	0.11	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Residue Nonfilterable	mg/L	2.0	33	28	5.3	10.7	0.50	4	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Total Suspended Solids	mg/L	5.0	32	26.4	5.6	14.5	0.39	5	Pass
18.1	S1519845984	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Total Suspended Solids	mg/L	1.0	49	42.0	6.5	13.3	0.49	4	Pass
Anions and Nutrients						**Ammonia Dissolved**									
	S15000964	E103117	Cariboo Pulp and Paper	10.09.14	WW	Nitrogen Ammonia Diss. (N)	mg/L	0.005	0.230	1.040	0.810	0.3	2.89	0	Fail
	S15000975	E103117	Cariboo Pulp and Paper	11.06.01	WW	Nitrogen Ammonia Diss. (N)	mg/L	0.005	0.900	2.370	1.470	0.7	2.17	0	Fail
	S1325876469	E103117	Cariboo Pulp and Paper	12.01.09	WW	Nitrogen Ammonia Diss. (N)	mg/L	0.005	1.630	1.960	0.330	0.6	0.59	4	Pass
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Nitrogen Ammonia Diss. (N)	mg/L	0.005	2.300	3.200	0.900	0.9	0.99	4	Pass
Anions and Nutrients						**Ammonia Total**									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Nitrogen Ammonia Total. (N)	mg/L	0.005	0.393	0.280	0.113	0.1	1.31	2	Fail
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Nitrogen Ammonia Total. (N)	mg/L	0.005	0.4300	0.459	0.029	0.1	0.21	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Ammonia Total (as N)	mg/L	0.025	0.7170	0.735	0.018	0.2	0.07	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Ammonia Total (as N)	mg/L	0.013	0.5110	0.547	0.036	0.2	0.21	5	Pass
Anions and Nutrients						**Nitrate and Nitrite (as N)**									
	S1481823473			17.01.17	WW	Nitrate and Nitrite (as N)	mg/L	0.063	NR	2.00	NC	0.7	NC		
Anions and Nutrients						**Nitrate Dissolved (as N)**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Nitrogen Nitrate Diss. (N)	mg/L	0.020	<0.020	<0.1	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Nitrogen Nitrate Total. (N)	mg/L	0.030	0.121	0.100	0.021	0.1	0.37	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Nitrogen Nitrate Total. (N)	mg/L	0.030	0.180	0.199	0.019	0.1	0.19	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Nitrate (as N)	mg/L	0.060	0.17	0.203	0.033	0.1	0.23	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Nitrate (as N)	mg/L	0.050	2.20	2.980	0.780	0.9	0.84	4	Pass
Anions and Nutrients						**Nitrite Disolved (as N)**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Nitrogen Nitrite Diss. (N)	mg/L	0.020	0.096	0.093	0.003	0.055	0.05	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Nitrogen Nitrite Total. (N)	mg/L	0.030	3.550	3.520	0.030	1.024	0.03	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Nitrogen Nitrite Total. (N)	mg/L	0.010	1.570	1.520	0.050	0.444	0.11	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Nitrite (as N)	mg/L	0.030	1.55	1.790	0.240	0.535	0.45	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Nitrite (as N)	mg/L	0.010	0.92	0.853	0.070	0.255	0.27	5	Pass
Anions and Nutrients						**Total Kjeldahl Nitrogen**									
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Nitrogen Kjeldahl Total (N)	mg/L	0.20	5.49	6.60	1.11	2.15	0.52	4	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Nitrogen Kjeldahl Total (N)	mg/L	0.20	3.25	3.75	0.50	1.34	0.37	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Nitrogen Kjeldahl Total (N)	mg/L	0.25	3.92	4.16	0.24	1.53	0.16	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Nitrogen Kjeldahl Total (N)	mg/L	0.10	4.84	5.11	0.27	1.59	0.17	5	Pass
Anions and Nutrients						**Orthophosphate - Dissolved**									
	S1325876469	E103117	Cariboo Pulp and Paper	14.03.06	WW		mg/L	0.001	0.440	0.465	0.025	0.133	0.19	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Orthophosphate	mg/L	0.010	0.660	0.550	0.110	0.170	0.65	4	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Orthophosphate	mg/L	0.010	0.239	0.221	0.018	0.077	0.23	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Orthophosphate Dissolved (as P)	mg/L	0.010	0.225	0.236	0.011	0.081	0.14	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Orthophosphate Dissolved (as P)	mg/L	0.010	0.728	0.728	0.000	0.220	0.00	5	Pass
Anions and Nutrients						**Phosphorous (P) - Dissolved**									
		E103118	Cariboo Pulp and Paper	14.03.06	WW	Phosphorus Dissolved	mg/L	0.020	0.570	0.408	0.162	0.144	1.13	2	Fail
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Phosphorus Dissolved	mg/L	0.020	0.632	0.624	0.008	0.205	0.04	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Phosphorus Dissolved	mg/L	0.02	0.344	0.34	0.004	0.124	0.03	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Phosphorus Dissolved	mg/L	0.02	0.358	0.308	0.05	0.115	0.43	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Phosphorus Dissolved	mg/L	0.02	0.89	0.898	0.008	0.282	0.03	5	Pass
Anions and Nutrients						**Phosphorous (P) - Total**									
	S1389036060	E103118	Cariboo Pulp and Paper	14.03.06	WW	Phosphorus Total	mg/L	0.020	0.762	0.813	0.051	0.258	0.20	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Phosphorus Total	mg/L	0.020	1.46	0.667	0.793	0.217	3.66	0	Fail
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Phosphorus Total	mg/L	0.020	0.583	0.682	0.099	0.221	0.45	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Phosphorus Total	mg/L	0.020	0.98	0.508	0.472	0.172	2.74	0	Fail
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Phosphorus Total	mg/L	0.200	1.24	1.180	0.06	0.617	0.10	5	Pass

Bacteriological Tests						**Coliform Bacteria - Fecal**								
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Coliform - fecal	CFU/100ml	2	72	110	38	42.0	0.90	4	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Coliform - fecal	CFU/MPN/100ml'	2	33	40	7	17.1	0.41	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	16.01.12	WW	Coliform - fecal	MPN/100ml	2	33	79	46	31.0	1.48	2	Fail
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Coliform Bacteria - Fecal	MPN/100ml	2	NR	17	NC	8.9	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Coliform Bacteria - Fecal	MPN/100ml	2	49	23				5	Pass
Bacteriological Tests						**Coliform Bacteria - Total**								
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Coliform - Total	CFU/100ml	2	35000	350	34650	74.1	467.58	0	Fail
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Coliform - Total	CFU/MPN/100ml'	2	79000	44000	35000	8963.3	3.90	0	Fail
	S1421350993	E103117	Cariboo Pulp and Paper	16.01.12	WW	Coliform - Total	MPN/100ml	2	130	130	0	29.3	0.00	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Coliform Bacteria - Total	MPN/100ml	2	NR	240	NC	51.7	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Coliform Bacteria - Total	MPN/100ml	2	79	79				5	Pass
Aggregate Organics						**BOD**								
	S1389036060	E103117	Cariboo Pulp and Paper	14.03.06	WW	Biochemical Oxygen Demand	mg/L	6.0	15.2	NR	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Biochemical Oxygen Demand	mg/L	6.0	31.6	35.00	3.4	18.4	0.18	5	Pass
	S1452530860	E103117	Cariboo Pulp and Paper	16.01.12	WW	Biochemical Oxygen Demand	mg/L	2.0	26.0	29.30	3.3	11.1	0.30	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Biochemical Oxygen Demand	mg/L	2.0	25.00	32.50	7.5	12.0	0.62	4	Pass
18.1	S1519845984	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Biochemical Oxygen Demand	mg/L	6.0	38.00	15.50	22.5	12.9	1.75	0	Fail
Bioassay						**LT50 Daphnia**								
		E103117	Cariboo Pulp and Paper	14.01.20	WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	0.0	NR	0.00	NC				
	S1421450301	E103117	Cariboo Pulp and Paper	15.01.20	WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	0.0	0.0	0.0	0			5	Pass
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Daphnia 48 hr LT 50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
	S1481826420	E103117	Cariboo Pulp and Paper	17.01.17	WW	Daphnia 48 hr LT 50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
18.1	S1519844748	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Daphnia 48 hr LT 50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
Bioassay						**LC50 Trout**								
		E103117	Cariboo Pulp and Paper	14.01.21	WW	Trout 96 hr LT50 in 100% Eff.	% Mort.	0.0	NR	0.0	NC				
	S1421450301	E103117	Cariboo Pulp and Paper	15.01.20	WW	Trout 96 hr LT50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Trout 96 hr LT50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
	S1481826420	E103117	Cariboo Pulp and Paper	17.01.17	WW	Trout 96 hr LT50 in 100% Eff.	% Mort.	0.0	0.0	0.0	0			5	Pass
18.1	S1519844748	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Trout 96 hr LT50 in 100% Eff.	% Mort.	0.0	30.0	0.0	30			4	Pass

Resin Fatty Acids						**Abietic Acid**								
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Abietic Acid	ug/L	5.0	<5.0	<5.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Abietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Abietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Abietic Acid	mg/L	0.0010	<0.0040	0.0107	NC	0.0	NC		
						Arachidic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Arachidic Acid	mg/L	0.0050	<0.0050	<0.0050	NC	NC	NC		
						Behenic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Behenic Acid	mg/L	0.0050	<0.0050	0.0070	NC	0.0	NC		
						12-Chlorodehydroabietic Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	12-Chlorodehydroabietic Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	12-Chlorodehydroabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	12-Chlorodehydroabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	12-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0040	<0.0010	NC	NC	NC		
						14-Chlorodehydroabietic Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	14-Chlorodehydroabietic Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	14-Chlorodehydroabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	14-Chlorodehydroabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	14-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0040	<0.0010	NC	NC	NC		
						Dehydroabietic Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Dehydroabietic Acid	ug/L	5.0	<5.0	<5.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Dehydroabietic Acid	ug/L	1.0	<1.0	1.60	NC	1.9	NC		
	S1481823473	E103117	Cariboo Pulp and Paper		WW	Dehydroabietic Acid	ug/L	1.0	1	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Dehydroabietic Acid	mg/L	0.0010	0.0129	0.0213	0.008	0.007	1.13	2	Fail
						Dichlorodehydroabietic Acid									
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Dichlorodehydroabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Dichlorodehydroabietic Acid	mg/L	0.0010	<0.0040	<0.0010	NC	NC	NC		
						Isopimaric & Palustric Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Isopimaric & Palustric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Isopimaric & Palustric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Isopimaric & Palustric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Isopimaric & Palustric Acid	ug/L	1.0	<2.0	1.40	NC	1.810	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Isopimaric & Palustric Acid	mg/L	0.0010	0.0136	0.0226	0.009	0.008	1.15	2	Fail
						Lauric Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Lauric Acid	mg/L	0.0050	<0.020	<0.0050	NC	NC	NC		
						Levopimaric Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Levopimaric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Levopimaric Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Levopimaric Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Levopimaric Acid	mg/L	0.0030	<0.0030	<0.0030	NC	NC	NC		
						Lignoceric Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Lignoceric Acid	mg/L	0.0050		0.0052	0.005	0.009	0.61	4	Pass
						Linoleic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Linoleic Acid	mg/L	0.0050	<0.0050	<0.0050	NC	NC	NC		
						Linolenic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Linolenic Acid	mg/L	0.0050	<0.0060	<0.0050	NC	NC	NC		
						Myristic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Myristic Acid	mg/L	0.0050	<0.0050	<0.0050	NC	NC	NC		
											0.000	0.000	NC		
											0.000	0.000	NC		
						Neoabietic Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Neoabietic Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Neoabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Neoabietic Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Neoabietic Acid	mg/L	0.0050	<0.0040	<0.0050	NC	NC	NC		
						Oleic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Oleic Acid	mg/L	0.0050	0.0113	0.0084	0.003	0.009	0.31	5	Pass
						Palmitic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Palmitic Acid	mg/L	0.0300	<0.040	<0.030	NC	NC	NC		
											0.000	0.000	NC		
											0.000	0.000	NC		
						Pimaric Acid									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Pimaric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Pimaric Acid	ug/L	1.0	<1.0	1.70	NC	1.895	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Pimaric Acid	ug/L	1.0	1.30	1.70	0.400	1.895	0.21	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Pimaric Acid	mg/L	0.0	0.01	0.01	0.005	0.004	1.00	4	Pass
Resin Fatty Acids						**Sandaracopimaric Acid**									
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Sandaracopimaric Acid	ug/L	3.0	<3.0	<3.0	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Sandaracopimaric Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Sandaracopimaric Acid	ug/L	1.0	<1.0	<1.0	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Sandaracopimaric Acid	mg/L	0.0010	0.0013	0.0023	0.001	0.002	0.48	4	Pass
						Stearic Acid									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Stearic Acid	mg/L	0.0300	<0.030	<0.030	NC	NC	NC		
						Total Fatty Acids									
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Total Fatty Acids	mg/L	0.0500	<0.050	<0.050	NC	NC	NC		
Resin Fatty Acids						**Total Resin Acids**									
	S1325876469	E103117	Cariboo Pulp and Paper	14.03.06	WW	Resin Acids in Water	mg/L	5.000	0.00	0.05	0.046	7.084	0.01	5	Pass
	S1421350993	E103117	Cariboo Pulp and Paper	15.01.20	WW	Resin Acids in Water	mg/L	0.010	<0.010	NR	NC	NC	NC		
	S1452533290	E103117	Cariboo Pulp and Paper	16.01.12	WW	Resin Acids in Water	mg/L	0.010	<0.010	<0.010	NC	NC	NC		
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	Total Resin Acids	mg/L	0.010	<0.010	<0.010	NC	NC	NC		
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	Total Resin Acids	mg/L	0.0100	0.0340	0.0680	0.034	0.033	1.02	4	Pass
Absorbable Organic Halides (AOX)						**AOX**									
	S15000964	E103117	Cariboo Pulp and Paper	10.09.14	WW	Adsorbable Organic Halide	mg/L	0.05	3.69	3.50	0.190	1.308	0.15	5	Pass
	S15000975	E103117	Cariboo Pulp and Paper	11.06.01	WW	Adsorbable Organic Halide	mg/L	0.10	3.80	3.23	0.570	1.283	0.44	5	Pass
	S1325876469	E103117	Cariboo Pulp and Paper	12.01.09	WW	Adsorbable Organic Halide	mg/L	0.10	3.40	3.13	0.270	1.248	0.22	5	Pass
	S1481823473	E103117	Cariboo Pulp and Paper	17.01.17	WW	AOX	mg/L	0.50	4.39	4.33	0.060	2.238	0.03	5	Pass
18.1	S1519841999	E103117	Cariboo Pulp and Paper	6-Mar-18	WW	AOX	mg/L	0.50	3.30	3.79	0.490	1.779	0.28	5	Pass

Notes:

Interpretive Notes:

1. The **Points Assigned** (Column O) are based on an industry standard grading scale. Available points are 5, 4, 2 and 1 (5 is the highest possible score). Scores of 0 and 2 demonstrate an unacceptable analytical result.

Key Notes:

NC : Not Completed or Not Calculable. NC denotes that a test result was either '*Not Reported*' or was "*Reported Below the Reportable Detection Limit (RDL)*".
2.1 Column N Cells that are highlighted dark green and boldened indicate results that deviate by a factor of 2 or greater or those that are categorized as NC. Cells with this designation require further scrutiny.
NC Column N Cells that are highlighted dark green and boldened and contain 'NC' require further scrutiny. These test results may not be valid, or the difference between a 'below detect' and a detect may be great enough to warrant further investigative actions.
na : Not applicable.
NR : Not Reported.
%Mort : Percent of mortality among test organisms which occurred during the full test period of an LC50 or LT50 bioassay.
NAL : Not Acutely Lethal = designated for a LC50 bioassay that did not result in a 50% mortality of test organisms during the 96 or 48 hour test period.

For more information please contact Ministry of Environment and Climate Change Strategy, Laboratory Services: 4th Floor - 525 Superior Street, Victoria, BC V8V 1T7 Phone: 778.698.4411

Permit: PE01199

May 02, 2018

To: **Domtar Pulp and Paper**

Re: **Revised Split Sampling Audit Summary Report**

Dear: Kristin Dangelmaier and Tiffany Cobb,

Thank you for participating in the Split Sampling Program. Environmental data produced under order or enactment such as those required by permit provide critical information upon which crucial decisions are made regarding environmental protection. For this reason it is incumbent upon the Province to ensure that environmental data is produced with a reliable level of quality. The Split Sampling Program is a robust audit mechanism that evaluates and monitors that quality by comparing the analytical results of your samples to those obtained by a Ministry representative.

The Split Sampling Program is a Quality Assurance Program administered by the Ministry of Environment and Climate Change Strategy. Evaluations of the Split Sample test results are conducted by the Ministry's Laboratory Standards and Quality Assurance Unit (LSQA). Since your last audit the LSQA unit has simplified the evaluation process through a revision of the Split Sampling Program which is reflected in this summary report.

Performance Evaluations

Split Sample audits are used to conduct an assessment of a permittee's sampling performance and a laboratory's analytical performance. Where possible a sample splitter is used to produce homogenous aliquots of sample material from a known source thereby reducing to the greatest degree possible, the potential impacts of media heterogeneity. The removal of this potential interference allows an evaluation to distinguish and report on the remaining aspects of producing representative environmental parameters. These remaining aspects include field QA/QC, sample handling, processing, preservation, shipping, laboratory processing and sample handling, laboratory equipment and instrumentation, QA/QC, and reporting.

Audit Definition and Performance Criteria

Each submission of split samples constitutes an *audit*. Audit testing is divided into *Water Chemistry, Toxicity and Microbiological* components although not all submissions include toxicity and or microbiological testing. Water chemistry results are evaluated via a statistical comparison of the permittee's laboratory results with the Ministry's laboratory results. An evaluation of microbiological test results are scored according to the grading scale developed for

Ministry of Environment Environmental Monitoring, Reporting & Economics Section
Environmental Sustainability and Strategic Policy Division
Mailing Address: PO Box 9341 Stn Prov Govt Victoria BC V8W 9M2
Telephone: 250 387-9938
Facsimile: 250 356-5496
Website: www.gov.bc.ca/env

the CMPT data assessment protocol. Toxicity test results are scored by absolute deviation. The maximum allowable deviation for a toxicity test is 31%.

Two criterion are applied to each audit; a *Percent of Failed Tests* with a 25% threshold and an overall *Performance Evaluation* which must achieve 70%. Each test result produces a statistical performance score of 5, 4, 2 or 0 *points* where 5 is the highest score and both 2 and 0 indicate an unacceptable (failed) test result. The average of all performance scores produced in a single audit constitutes the overall Performance Evaluation. Evaluations that result in a percentage of Failed Tests below 25 and a Performance Evaluation equal to or greater than 70% constitutes an audit pass.

2018 Audit Summary
The analytical results for all tests included in this audit have been tabulated in the attached 'Table' document. The information provided in our telephone conversation and in the requisition forms you provided has been used to revise the results of your 2018 Split Sample Audit. The revised data is reflected in the attached pdf document titled 'Domtar_SS Audit.2018.2".

As reported to LSQA your acids samples were damaged on route to the laboratory and as such were not analyzed or included in this audit. The total number of tests included in your audit is 79. The scores produced by those tests provide a Performance Evaluation of 79% with a percentage of failed tests below 25 resulting in an audit pass. Thank you very much for your continuing deployment of Quality Assurance measures.

For more information on the calculation of the performance scores or any other information regarding the Split Sampling Program, please feel free to contact me. For any permit related question please contact your Environmental Protection Officer.

Blair R Irwin, P.Ag., EP, B.Sc.,
Senior Quality Management Analyst
Phone: 778-698-4411
Email: Blair.Irwin@gov.bc.ca

cc: Jack Green

SPLIT SAMPLNG QUALITY ASSURANCE PROGRAM - AUDIT REPORT

Permit Number: PE01199
Client Name: Domtar Inc.
Regional Office: Williams Lake
EPD officer: Jack Green

Date of Last Amendment: April 2018
Amended by: Blair R Irwin
Audit Date: 27 April, 2018

Ensure that the 'functions' are set in each of the newly actived cells within the evaluation block of the spreadsheet.

Manual Data Entry Block											Automated Evaluation Block				
Audit No.	**Requisition No.**	**Sample Site ID**	**Sample Location/ Site Name**	**Sample Date**	**Sample Type**	**Parameter**	**Units**	**MOE LDL**	**MOE Results**	**Permit Results**	**Absolute Deviation**	**Acceptable Deviation**	**Deviation Factor**	**Points Assigned**	**Pass/Fail**
Physical Tests						**Colour**									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Color	Col. Units	10	731	614	117.0	117.5	1.0	4	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Color	CU	5	248	212	36.0	42.1	0.9	4	Pass
											0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
Physical Tests						**pH**									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	pH	pH Units	0.1	8.0	7.9	0.1	1.3	0.1	5	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	pH	pH Units	0.1	7.5	7.2	0.3	1.2	0.3	5	Pass
					WW	pH	pH Units				0.0	0.0	NC		
					WW	pH	pH Units				0.0	0.0	NC		
					WW	pH	pH Units				0.0	0.0	NC		
Physical Tests						**Conductivity**									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Specific Conductance	µS/cm	2.0	1510.0	1570	60.0	216.4	0.3	5	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Specific Conductance	µS/cm	2.0	979.0	643	336.0	141.3	2.4	0	Fail
					WW	Specific Conductance	µS/cm				0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
						Hardness									
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Hardness (as $CaCO_3$)	mg/L	0.50	97.60	*NR	NC	14.5	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
Physical Tests						**Total Suspended Solids (aka Residue Nonfilterable)**									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Residue Nonfilterable	mg/L	NR	NR	42.0	NC	NC	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Residue Nonfilterable	mg/L	3.0	28.5	24.4	4.1	8.3	0.5	4	Pass
					WW	Residue Nonfilterable	mg/L				0.0	0.0	NC		
					WW	Residue Nonfilterable	mg/L				0.0	0.0	NC		
					WW	Residue Nonfilterable	mg/L				0.0	0.0	NC		
						Total Solids									
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Total Solids	mg/L	20.0	728.0	*NR	NC	131.2	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		
											0.0	0.0	NC		

						Ammonia Total (as N)								
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Nitrogen Ammonia Total. (N)	mg/L	0.005	0.063	0.076	0.013	0.02	0.8	4	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Nitrogen Ammonia Total. (N)	mg/L	0.013	0.827	1.2000	0.373	0.14	2.8	0	Fail
											0.000	0.00	NC		
											0.000	0.00	NC		
											0.000	0.00	NC		
											0.000	0.00	NC		
Anions and Nutrients						**Nitrate Dissolved (as N)**								
18.1	S1520973847	E217081	Final Lagoon Discharge	15-Mar-18	WW	Nitrate (as N)	mg/L	NR	NR	0.552	NC	NC	NC	5	Pass
					WW	Nitrate (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrate (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrate (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrate (as N)	mg/L				0.000	0.00	NC		
Anions and Nutrients						**Nitrite Disolved (as N)**								
18.1	S1520973847	E217081	Final Lagoon Discharge	15-Mar-18	WW	Nitrite (as N)	mg/L	NR	NR	0.038	NC	NC	NC	5	Pass
					WW	Nitrite (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrite (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrite (as N)	mg/L				0.000	0.00	NC		
					WW	Nitrite (as N)	mg/L				0.000	0.00	NC		
Anions and Nutrients						**Total Kjeldahl Nitrogen**								
18.1	S1520973847	E217081	Final Lagoon Discharge	15-Mar-18	WW	Total Kjeldahl Nitrogen	mg/L	NR	NR	3.07	NC	NC	NC	5	Pass
					WW	Total Kjeldahl Nitrogen	mg/L				0.00	0.00	NC		
					WW	Total Kjeldahl Nitrogen	mg/L				0.00	0.00	NC		
					WW	Total Kjeldahl Nitrogen	mg/L				0.00	0.00	NC		
					WW	Total Kjeldahl Nitrogen	mg/L				0.00	0.00	NC		
Anions and Nutrients						**Orthophosphate - Dissolved**								
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Orthophosphate	mg/L	0.010	0.616	0.596	0.020	0.1	0.2	5	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Orthophosphate	mg/L	0.010	0.115	0.129	0.014	0.0	0.5	4	Pass
					WW	Orthophosphate	mg/L				0.000	0.0	NC		
					WW		mg/L				0.000	0.0	NC		
Anions and Nutrients						**Phosphorous (P) - Dissolved**								
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Phosphorus Dissolved	mg/L	0.020	0.650	0.700	0.050	0.1	0.4	5	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Phosphorus Dissolved	mg/L	0.010	0.419	0.164	0.255	0.1	3.5	0	Fail
					WW	Phosphorus Dissolved	mg/L				0.000	0.0	NC		
					WW	Phosphorus Dissolved	mg/L				0.000	0.0	NC		
					WW	Phosphorus Dissolved	mg/L				0.000	0.0	NC		
Anions and Nutrients						**Phosphorous (P) - Total**								
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Phosphorus Total	mg/L	0.200	0.930	0.990	0.060	0.5	0.1	5	Pass
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Phosphorus Total	mg/L	0.030	0.523	0.506	0.017	0.2	0.1	5	Pass
					WW	Phosphorus Total	mg/L				0.000	0.0	NC		
					WW	Phosphorus Total	mg/L				0.000	0.0	NC		
					WW	Phosphorus Total	mg/L				0.000	0.0	NC		

Aggregate Organics						**BOD**									
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Biochemical Oxygen Demand	mg/L	6.0	17.8	18.7	0.9	13.5	0.1	5	Pass
					WW	Biochemical Oxygen Demand	mg/L				0.0	0.0	**NC**		
					WW	Biochemical Oxygen Demand	mg/L				0.0	0.0	**NC**		
					WW	Biochemical Oxygen Demand	mg/L				0.0	0.0	**NC**		
Bioassay						**LT50 Daphnia**									
18.1		E217081	Final Lagoon Discharge	15-Mar-18	WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	NR	0.0	0.0	0.000		**NC**	5	Pass
					WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	NR			0.000		**NC**		
					WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	NR			0.000		**NC**		
					WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	NR			0.000		**NC**		
					WW	Daphnia 48 hr LT 50 in 100% Eff.	% mort.	NR			0.000		**NC**		
Bioassay						**LC50 Trout**									
18.1		E217081	Final Lagoon Discharge		WW	Trout 96 hr LC50 in 100% Effl.	% Mort.	NR	0.0	0.0	0.000		**NC**	5	Pass
					WW	Trout 96 hr LC50 in 100% Effl.	% Mort.	NR			0.000		**NC**		
					WW	Trout 96 hr LC50 in 100% Effl.	% Mort.	NR			0.000		**NC**		
					WW	Trout 96 hr LC50 in 100% Effl.	% Mort.	NR			0.000		**NC**		
					WW	Trout 96 hr LC50 in 100% Effl.	% Mort.	NR			0.000		**NC**		

Resin Fatty Acids						**Abietic Acid**									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Abietic Acid	mg/L	0.0010	0.0014	LS	NC	0.0	NC		
					WW	Abietic Acid	mg/L				0.000	0.0	NC		
					WW	Abietic Acid	mg/L				0.000	0.0	NC		
						Arachidic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Arachidic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Arachidic Acid	mg/L				0.000	0.0	NC		
					WW	Arachidic Acid	mg/L				0.000	0.0	NC		
						Behenic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Behenic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Behenic Acid	mg/L				0.000	0.0	NC		
					WW	Behenic Acid	mg/L				0.000	0.0	NC		
						12-Chlorodehydroabietic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	12-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
					WW	12-Chlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
					WW	12-Chlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
						14-Chlorodehydroabietic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	14-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
					WW	14-Chlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
					WW	14-Chlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
						Dehydroabietic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Dehydroabietic Acid	mg/L	0.0010	0.0027	LS	NC	0.0	NC		
					WW	Dehydroabietic Acid	mg/L				0.000	0.0	NC		
					WW	Dehydroabietic Acid	mg/L				0.000	0.0	NC		
						Dichlorodehydroabietic Acid									
	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Dichlorodehydroabietic Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
#					WW	Dichlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
					WW	Dichlorodehydroabietic Acid	mg/L				0.000	0.0	NC		
						Isopimaric & Palustric Acid									
#	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Isopimaric & Palustric Acid	mg/L	0.0060	<0.0060	LS	NC	NC	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
						Lauric Acid									
#	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Isopimaric & Palustric Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.0	NC		
						Levopimaric Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Levopimaric Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
					WW	Levopimaric Acid	mg/L				0.000	0.0	NC		
					WW	Levopimaric Acid	mg/L				0.000	0.0	NC		
						Lignoceric Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Lignoceric Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Lignoceric Acid	mg/L				0.000	0.0	NC		
					WW	Lignoceric Acid	mg/L				0.000	0.0	NC		
						Linoleic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Linoleic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Linoleic Acid	mg/L				0.000	0.0	NC		
					WW	Linoleic Acid	mg/L				0.000	0.0	NC		
						Linolenic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Linolenic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Linolenic Acid	mg/L				0.000	0.0	NC		
					WW	Linolenic Acid	mg/L				0.000	0.0	NC		
						Myristic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Myristic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Myristic Acid	mg/L				0.000	0.0	NC		
					WW	Myristic Acid	mg/L				0.000	0.0	NC		
						Neoabietic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Neoabietic Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
					WW	Neoabietic Acid	mg/L				0.000	0.0	NC		
						Oleic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Oleic Acid	mg/L	0.0050	<0.0050	LS	NC	NC	NC		
					WW	Oleic Acid	mg/L				0.000	0.0	NC		
					WW	Oleic Acid	mg/L				0.000	0.0	NC		
						Palmitic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Palmitic Acid	mg/L	0.0200	<0.020	LS	NC	NC	NC		
					WW	Palmitic Acid	mg/L				0.000	0.0	NC		
					WW	Palmitic Acid	mg/L				0.000	0.0	NC		
						Primaric Acid									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Pimaric Acid	ug/L	0.0010	0.0077	0.0085	0.001	0.0	0.2	5	Pass
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Pimaric Acid	mg/L	0.0010	0.0059	LS	NC	0.0	NC		
					WW	Pimaric Acid	mg/L				0.000	0.0	NC		
						Sandaracopimaric Acid									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Sandaracopimaric Acid	ug/L	0.0010	<0.001	<0.003	NC	NC	NC		
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Sandaracopimaric Acid	mg/L	0.0010	<0.0010	LS	NC	NC	NC		
					WW	Sandaracopimaric Acid	mg/L				0.000	0.0	NC		
						Stearic Acid									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Stearic Acid	mg/L	0.0200	<0.020	LS	NC	NC	NC		
					WW	Stearic Acid	mg/L				0.000	0.0	NC		
					WW	Stearic Acid	mg/L				0.000	0.0	NC		
						Total Fatty Acids									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Total Fatty Acids	mg/L	0.0500	<0.050	LS	NC	NC	NC		
					WW	Total Fatty Acids	mg/L				0.000	0.0	NC		
					WW	Total Fatty Acids	mg/L				0.000	0.0	NC		
						Total Resin Acids									
	S1464110135	E217081	Final Lagoon Discharge	25-May-16	WW	Resin Acids in Water	mg/L	0.0100	0.0190	0.0210	0.002	0.020	0.1	5	Pass
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Resin Acids in Water	mg/L	0.0100	<0.010	*NR	NC	NC	NC		
					WW	Resin Acids in Water	mg/L				0.000	0.000	NC		
					WW	Resin Acids in Water	mg/L				0.000	0.000	NC		
					WW	Resin Acids in Water	mg/L				0.000	0.000	NC		
Absorbable Organic Halides (AOX)						**AOX**									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Adsorbable Organic Halide	mg/L	0.2500	1.3400	0.9000	0.44	0.83	0.5	4	Pass
					WW	Adsorbable Organic Halide	mg/L				0.00	0.00	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.00	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.00	NC		

Metals						Total									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	Hardness	mg/L	0.5	248	*NR	NC	35.8	NC		
											0.00	0.0	NC		
											0.00	0.0	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Aluminum	mg/L	0.003	0.15	0.35	0.201	0.026	7.8	0	Fail
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Antimony	mg/L	0.00010	0.00018	0.00019	0.000	0.000	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Arsenic	mg/L	0.00010	0.00082	0.00085	0.000	0.000	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Barium	mg/L	0.00005	0.08790	0.18300	0.095	0.013	7.6	0	Fail
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Beryllium	mg/L	0.00010	<0.00010	<0.00010	NC	NC	NC	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Bismuth	mg/L	0.00005	<0.000050	<0.000050	NC	NC	NC	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Boron	mg/L	0.01000	0.02900	0.14400	0.115	0.018	6.3	0	Fail
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Cadmium	mg/L	0.000005	0.000279	0.000297	0.000	0.000	0.4	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Calcium	mg/L	0.05000	33.20000	35.40000	2.200	4.766	0.5	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Chromium	mg/L	0.00010	0.00232	0.00259	0.000	0.000	0.6	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Colbalt	mg/L	0.00010	0.00017	0.00019	0.000	0.000	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Copper	mg/L	0.00050	0.00313	0.00395	0.001	0.001	0.7	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Iron	mg/L	0.00500	0.22400	0.25700	0.033	0.039	0.9	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Lead	mg/L	0.00005	0.00047	0.00061	0.00015	0.00014	1.1	2	Fail
											0.00000	0.00000	NC		
											0.00000	0.00000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Magnesium	mg/L	0.00500	3.60000	3.86000	0.260	0.516	0.5	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Manganese	mg/L	0.00010	0.19100	0.23600	0.045	0.027	1.7	0	Fail
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Molybdenun	mg/L	0.00005	0.00190	0.00198	0.000	0.000	0.2	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Nickel	mg/L	0.00050	0.00183	0.00232	0.000	0.001	0.5	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Phosphorous	mg/L	0.03000	0.52300	0.53200	0.009	0.116	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Potassium	mg/L	0.05000	13.20000	13.00000	0.200	1.937	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Selenium	mg/L	0.00005	0.00018	0.00018	0.000	0.000	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Silicon	mg/L	0.10000	4.57000	4.79000	0.220	0.788	0.3	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Silver	mg/L	0.00001	0.00006	0.00006	0.000002	0.000023	0.1	5	Pass
											0.000000	0.000000	NC		
											0.000000	0.000000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Sodium	mg/L	0.050	138.000	151.000	13.000	19.587	0.7	4	Pass
							mg/L				0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Strontium	mg/L	0.00020	0.14300	0.14000	0.003	0.021	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Sulfur	mg/L	0.50	113.00	114.00	1.000	16.688	0.1	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Thallium	mg/L	0.00001	<0.000010	0.00002	NC	NC	NC	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Tin	mg/L	0.00010	0.00084	0.00090	0.00006	0.00026	0.2	5	Pass
											0.00000	0.00000	NC		
											0.00000	0.00000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Titanium	mg/L	0.00030	0.00471	0.00602	0.00131	0.00109	1.2	2	Fail
											0.00000	0.00000	NC		
											0.00000	0.00000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Uranium	mg/L	0.00001	0.00044	0.00050	0.000	0.000	0.7	4	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	Vanadium	mg/L	0.00050	0.00286	0.00283	0.000	0.001	0.0	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		
18.1	S1520886320	E217081	Final Lagoon Discharge		WW	Zinc	mg/L	0.00300	0.01730	0.01940	0.002	0.007	0.3	5	Pass
											0.000	0.000	NC		
											0.000	0.000	NC		

Metals						Dissolved									
18.1	S1520889146	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Hardness**	mg/L	0.5	248	*NR	NC	35.8	**NC**		
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Aluminum**	mg/L	0.0010	0.0799	0.0718	0.00810	0.01271	0.6	4	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Antimony**	mg/L	0.00020	<0.00020	0.00016	NC	NC	**NC**	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Arsenic**	mg/L	0.00010	0.00078	0.00077	0.00001	0.00025	0.0	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Barium**	mg/L	0.00005	0.04500	0.07930	0.03430	0.00643	**5.3**	0	Fail
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Beryllium**	mg/L	0.00010	<0.00010	<0.00010	NC	NC	**NC**	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Bismuth**	mg/L	0.00005	<0.000050	<0.000050	NC	NC	**NC**	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Boron**	mg/L	0.01000	0.02900	0.02800	0.00100	0.01824	0.1	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Cadmium**	mg/L	0.0000050	0.0000861	0.000094	0.00001	0.00002	0.4	5	Pass
											0.00000	0.00000	**NC**		
											0.00000	0.00000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Calcium**	mg/L	0.05000	32.50000	33.40000	0.90	4.7	0.2	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Chromium**	mg/L	0.00010	0.00178	0.00179	0.00	0.0	0.0	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Colbalt**	mg/L	0.00010	<0.00010	<0.00010	NC	NC	**NC**	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Copper**	mg/L	0.00020	0.00157	0.00172	0.00	0.0	0.3	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Iron**	mg/L	0.00500	0.12300	0.14500	0.02	0.0	0.9	4	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Lead**	mg/L	0.00005	0.00018	0.00024	0.00	0.0	0.5	4	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Magnesium**	mg/L	0.00500	3.99000	3.69000	0.30	0.6	0.5	4	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Manganese**	mg/L	0.00010	0.18800	0.07510	0.11	0.0	**4.2**	0	Fail
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Molybdenun**	mg/L	0.00005	0.00168	0.00170	0.00	0.0	0.1	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Nickel**	mg/L	0.00050	0.00161	0.00142	0.00	0.0	0.2	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Phosphorous**	mg/L	0.01000	0.41900	0.20200	0.22	0.1	**3.0**	0	Fail
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Potassium**	mg/L	0.05000	15.10000	13.90000	1.20	2.2	0.5	4	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Selenium**	mg/L	0.000050	0.000017	0.00015	0.000135	0.000073	1.8	0	Fail
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Silicon**	mg/L	0.05000	4.32000	4.45000	0.13	0.68	0.2	5	Pass
											0.00	0.00	**NC**		
											0.00	0.00	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Silver**	mg/L	0.000010	0.000017	0.000018	0.000001	0.000017	0.1	5	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Sodium**	mg/L	0.050	177.000	159.000	18.00	25.1	0.7	4	Pass
							mg/L				0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Strontium**	mg/L	0.00020	0.13600	0.14200	0.0060	0.0195	0.3	5	Pass
											0.0000	0.0000	**NC**		
											0.0000	0.0000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Sulfur**	mg/L	0.50	103.00	107.00	4.00	15.3	0.3	5	Pass
											0.00	0.0	**NC**		
											0.00	0.0	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Thallium**	mg/L	0.00001	0.00001	0.00001	0.000001	0.000016	0.1	5	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Tin**	mg/L	0.00010	0.00066	0.00072	0.000060	0.000235	0.3	5	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Titanium**	mg/L	0.00030	0.00199	0.00198	0.000010	0.000706	0.0	5	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Uranium**	mg/L	0.00001	0.00031	0.00036	0.000044	0.000058	0.8	4	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Vanadium**	mg/L	0.00050	0.00237	0.00245	0.000080	0.001042	0.1	5	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		
18.1	S1520886320	E217081	Final Lagoon Discharge	15-Mar-18	WW	**Zinc**	mg/L	0.00100	0.01200	0.00920	0.002800	0.003111	0.9	4	Pass
											0.000000	0.000000	**NC**		
											0.000000	0.000000	**NC**		

Notes:

Interpretive Notes:

1. The **Points Assigned** (Column O) are based on an industry standard grading scale. Available points are 5, 4, 2 and 0 (5 is the highest possible score). Scores of 0 and 2 demonstrate an unacceptable analytical result.

Key Notes:

NC	: **Not Completed** or **Not Calculable**. NC denotes that a test result was either '*Not Reported*' of was '*Reported Below the Reportable Detection Limit (RDL)*'.
2.1	Column N Cells that are highlighted **dark green and boldened** indicate results that **deviate by a factor of 2 or greater** or those that are **categorized as NC**. Cells with this designation **require further scrutiny**.
NC	Column N Cells that are highlighted **dark green and boldened** and contain 'NC' **require further scrutiny**. These test results may not be valid, or the difference between a 'below detect' and a detect may be great enough to warrant further investigative actions.
na	: **Not Applicable**.
NR	: **Not Reported**. A performance score of 0 is assigned for required test results that are not reported.
***NR/SL**	: **Not Required** for submission or inclusion of the Audit/**Samples Lost** and are therefore not included in the Audit.
%Mort	: Percent of mortality among test organisms which occurred during the full test period of an LC50 or LT50 bioassay.
NAL	: Not Acutley Lethal = designated for an LC50 bioassay test that did not result in a 50% mortality of test organisms during the 48 or 96 hour test period.

For more information please contact Ministry of Environment and Climate Change Strategy, Laboratory Services: 4th Floor - 525 Superior Street, Victoria, BC V8V 1T7 Phone: 778.698.4411

BRITISH COLUMBIA

Permit:

Date: 07 May, 2018

To: Quesnel River Pulp Company

Re: 2018 Split Sample Audit Results

Dear: Margot Gagne

Thank you for participating in the Split Sampling Program. Environmental data produced under order or enactment such as those required by permit provide critical information upon which crucial decisions are made regarding environmental protection. For this reason it is incumbent upon the Province to ensure that environmental data is produced with a reliable level of quality. The Split Sampling Program is a robust audit mechanism that evaluates and monitors that quality by comparing the analytical results of your samples to those obtained by a Ministry representative.

The Split Sampling Program is a Quality Assurance Program administered by the Ministry of Environment and Climate Change Strategy. Evaluations of the Split Sample test results are conducted by the Ministry's Laboratory Standards and Quality Assurance Unit (LSQA). Since your last audit the LSQA unit has simplified the evaluation process through a revision of the Split Sampling Program which is reflected in this summary report.

Performance Evaluations

Split Sample audits are used to conduct an assessment of a permittee's sampling performance and a laboratory's analytical performance. Where possible a sample splitter is used to produce homogenous aliquots of sample material from a known source thereby reducing to the greatest degree possible, the potential impacts of media heterogeneity. The removal of this potential interference allows an evaluation to distinguish and report on the remaining aspects of producing representative environmental parameters. These remaining aspects include field QA/QC, sample handling, processing, preservation, shipping, laboratory processing and sample handling, laboratory equipment and instrumentation, QA/QC, and reporting.

Audit Definition and Performance Criteria

Each submission of split samples constitutes an *audit*. Audit testing is divided into *Water Chemistry, Toxicity and Microbiological* components although not all submissions include toxicity and or microbiological testing. Water chemistry results are evaluated via a statistical comparison of the permittee's laboratory results with the Ministry's laboratory results. An evaluation of microbiological test results are scored according to the grading scale developed for

Ministry of Environment | Environmental Monitoring, Reporting & Economics Section, Environmental Sustainability and Strategic Policy Division | Mailing Address: PO Box 9341 Stn Prov Govt Victoria BC V8W 9M2 | Telephone: 250 387-9938 Facsimile: 250 356-5496 Website: www.gov.bc.ca/env

the CMPT data assessment protocol. Toxicity test results are scored by absolute deviation. The maximum allowable deviation for a toxicity test is 30%.

Two criterion are applied to each audit; a *Percent of Failed Tests* with a 25% threshold and an overall *Performance Evaluation* which must achieve 70%. Each test result produces a statistical performance score of 5, 4, 2 or 0 *points* where 5 is the highest score and both 2 and 0 indicate an unacceptable (failed) test result. The average of all performance scores produced in a single audit constitutes the overall Performance Evaluation. Evaluations that result in a percentage of Failed Tests below 25 and a Performance Evaluation equal to or greater than 70% constitutes an audit pass.

2018 Audit Summary
The analytical results for all tests included in this audit have been tabulated in the attached 'Table' document. Although every effort is made to ensure accurate transcriptions have been afforded in this audit you are strongly encouraged to scrutinize the table document.

The total number of tests included in your audit is 96. The scores produced by those tests provide a Performance Evaluation of 74% with a percentage of failed tests below 25 resulting in an audit pass. Thank you very much for your continuing deployment of Quality Assurance measures. Please review the table. You will notice that tests that were not reported by Quesnel River Pulp Company are assigned a performance score of 0, although metals tests not reported (NR) in this year's audit were not assigned a value and were not included in the audit. Performance scores assigned to each test affect your audit's performance evaluation score, the number of failed tests in an audit, and ultimately the pass/fail result of your audit. To ensure that you are receiving the maximum performance score confirm with your Ministry representative to ensure your audit includes the full list of analyte tests.

Client Name:	Quesnel River Pulp
Audit No.:	18.1
Requisition No.:	S1520973847
Sample Date:	20-Mar-18
Total Tests Included:	96
Total Points Assigned:	357
Failed Test Results:	20
Percent of Failed Tests:	21%
Performance Evaluation:	74%
Audit Result:	PASS

For more information on the calculation of the performance scores or any other information regarding the Split Sampling Program, please feel free to contact me. For any permit related question please contact your Environmental Protection Officer.

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Senior Quality Management Analyst
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cc: Jack Green

SPLIT SAMPLNG QUALITY ASSURANCE PROGRAM - AUDIT REPORT

Permit Number: PE5803
Client Name: Quesnel River Pulp Company
Regional Office: Williams Lake
EPD officer: Jack Green

Date of Last Amendment: 22 May, 2018
Amended by: BRI

Ensure that the 'functions' are set in each of the newly actived cells within the evaluation block of the spreadsheet.

Manual Data Entry Block											Automated Evaluation Block				
Audit Item	Requisition No.	Sample Site ID	Sample Location/ Site Name	Sample Date	Sample Type	Parameter	Units	MOE LDL	MOE Results	Permit Results	Absolute Deviation	Acceptable Deviation	Deviation Factor	Points Assigned	Pass/ Fail
Physical Tests						**Colour**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Color	Col. Units	50	1840	1720	120.0	330.9	0.4	5	Pass
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Color	Col. Units	50	1500	1580	80.0	282.8	0.3	5	Pass
					WW	Color	Col. Units				0.0	0.0	NC		
					WW	Color	Col. Units				0.0	0.0	NC		
					WW	Color	Col. Units				0.0	0.0	NC		
Physical Tests						**pH**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	pH	pH Units	0.10	8.45	7.84	0.61	1.34	0.5	4	Pass
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	pH	pH Units	0.10	8.38	7.44	0.94	1.33	0.7	4	Pass
					WW	pH	pH Units				0.00	0.00	NC		
					WW	pH	pH Units				0.00	0.00	NC		
					WW	pH	pH Units				0.00	0.00	NC		
Physical Tests						**Conductivity**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Specific Conductance	μS/cm	2.0	3250	3370	120.00	462.45	0.3	5	Pass
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Specific Conductance	μS/cm	2.0	2770	2680	90.00	394.57	0.2	5	Pass
					WW	Specific Conductance	μS/cm				0.00	0.00	NC		
					WW	Specific Conductance	μS/cm				0.00	0.00	NC		
					WW	Specific Conductance	μS/cm				0.00	0.00	NC		
Physical Tests						**Volatile Suspended Solids (aka Residue Nonfilterable - Volatile)**									
18.1	S1520969866	E103144	QRP Final Discharge	19-Mar-18	WW	Residue Nonfilterable- Volatile	mg/L	3.0	261	270	9.00	41.15	0.2	5	Pass
					WW	Residue Nonfilterable- Volatile	mg/L				0.00	0.00	NC		
					WW	Residue Nonfilterable- Volatile	mg/L				0.00	0.00	NC		
					WW	Residue Nonfilterable- Volatile	mg/L				0.00	0.00	NC		
Physical Tests						**Total Suspended Solids (aka Residue Nonfilterable)**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Residue Nonfilterable	mg/L	15.0	245	190	55.00	55.86	1.0	4	Pass
18.1	S1520969866	E103144	QRP Final Discharge	19-Mar-18	WW	Residue Nonfilterable	mg/L	3.0	291	280	11.00	45.40	0.2	5	Pass
					WW	Residue Nonfilterable	mg/L				0.00	0.00	NC		
					WW	Residue Nonfilterable	mg/L				0.00	0.00	NC		
					WW	Residue Nonfilterable	mg/L				0.00	0.00	NC		
Anions and Nutrients						**Ammonia Total**									
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Nitrogen Ammonia Total. (N)	mg/L	0.005	0.187	0.1810	0.0060	0.0335	0.2	5	Pass
					WW	Ammonia Total (as N)	mg/L				0.0000	0.0000	NC		
											0.0000	0.0000			
											0.0000	0.0000			
Anions and Nutrients						**Nitrate Dissolved (as N)**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Nitrogen Nitrate Diss. (N)	mg/L	0.060	<0.006	<0.005	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Nitrogen Nitrate Diss. (N)	mg/L	0.060	<0.060	<0.005	NC	NC	NC	5	Pass
					WW	Nitrogen Nitrate Diss. (N)	mg/L				0.0000	0.0000	NC		
					WW	Nitrogen Nitrate Diss. (N)	mg/L				0.0000	0.0000	NC		
					WW	Nitrogen Nitrate Diss. (N)	mg/L				0.0000	0.0000	NC		
Anions and Nutrients						**Nitrite Disolved (as N)**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Nitrogen Nitrite Diss. (N)	mg/L	0.001	0.026	<0.005	NC	0.0	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Nitrogen Nitrite Diss. (N)	mg/L	0.020	0.037	<0.005	NC	0.0	NC	4	Pass
					WW	Nitrogen Nitrite Diss. (N)	mg/L				0.000	0.000	NC		
					WW	Nitrogen Nitrite Diss. (N)	mg/L				0.000	0.000	NC		
					WW	Nitrogen Nitrite Diss. (N)	mg/L				0.000	0.000	NC		
Anions and Nutrients						**Total Kjeldahl Nitrogen**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Nitrogen Kjeldahl Total (N)	mg/L	0.50	7.88	16.80	8.92	1.82	4.9	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Nitrogen Kjeldahl Total (N)	mg/L	1.30	21.90	8.12	13.78	4.94	2.8	0	Fail
					WW	Nitrogen Kjeldahl Total (N)	mg/L				0.00	0.00	NC		
					WW	Nitrogen Kjeldahl Total (N)	mg/L				0.00	0.00	NC		
					WW	Nitrogen Kjeldahl Total (N)	mg/L				0.00	0.00	NC		
Anions and Nutrients						**Orthophosphate - Dissolved**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Orthophosphate	mg/L	0.010	0.133	0.700	0.567	0.033	17.2	0	Fail
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Orthophosphate	mg/L	0.010	0.745	0.500	0.245	0.120	2.1	0	Fail
					WW	Orthophosphate	mg/L				0.000	0.000	NC		
Anions and Nutrients						**Total Organic Carbon**									
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Total Organic Carbon	mg/L	NR	NR	263.000	NC	NC	NC	5	Pass
					WW	Total Organic Carbon	mg/L				0.000	0.000	NC		
					WW	Total Organic Carbon	mg/L				0.000	0.000	NC		
					WW	Total Organic Carbon	mg/L				0.000	0.000	NC		
Anions and Nutrients						**Dissolved Organic Carbon**									
18.1	S1520969866	E103144	QRP Final Discharge	20-Mar-18	WW	Dissolved Organic Carbon	mg/L	NR	NR	240.000	NC	NC	NC	5	Pass
					WW	Dissolved Organic Carbon	mg/L				0.000	0.000	NC		
					WW	Dissolved Organic Carbon	mg/L				0.000	0.000	NC		
					WW	Dissolved Organic Carbon	mg/L				0.000	0.000	NC		
Anions and Nutrients						**Phosphorous (P) - Dissolved**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Phosphorus Dissolved	mg/L	0.020	0.320	0.083	0.237	0.074	3.2	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Phosphorus Dissolved	mg/L	0.200	1.030	0.590	0.440	0.429	1.0	4	Pass
					WW	Phosphorus Dissolved	mg/L				0.000	0.000	NC		
					WW	Phosphorus Dissolved	mg/L				0.000	0.000	NC		
					WW	Phosphorus Dissolved	mg/L				0.000	0.000	NC		
Anions and Nutrients						**Phosphorous (P) - Total**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Phosphorus Total	mg/L	0.200	1870	NR	NC	264.7	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Phosphorus Total	mg/L	0.200	2.550	2.630	0.080	0.643	0.1	5	Pass
					WW	Phosphorus Total	mg/L				0.000	0.000	NC		
					WW	Phosphorus Total	mg/L				0.000	0.000	NC		
					WW	Phosphorus Total	mg/L				0.000	0.000	NC		

Bacteriological Tests						**Coliform Bacteria - Fecal**									
		E103144	QRP Final Discharge		WW	Coliform - fecal									
					WW	Coliform - fecal									
					WW	Coliform - fecal									
					WW	Coliform - fecal									
					WW	Coliform - fecal									
Bacteriological Tests						**Coliform Bacteria - Total**									
		E103144	QRP Final Discharge		WW	Coliform - Total									
					WW	Coliform - Total									
					WW	Coliform - Total									
					WW	Coliform - Total									
					WW	Coliform - Total									
Aggregate Organics						**BOD**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Biochemical Oxygen Demand	mg/L	2.0	54.0	46.0	8.00	10.47	0.8	4	Pass
	S1520973847	E103144	QRP Final Discharge	19-Mar-18	WW	Biochemical Oxygen Demand	mg/L	6.0	39.7	55.0	15.30	14.10	1.1	2	Fail
					WW	Biochemical Oxygen Demand	mg/L				0.00	0.00	NC		
					WW	Biochemical Oxygen Demand	mg/L				0.00	0.00	NC		
					WW	Biochemical Oxygen Demand	mg/L				0.00	0.00	NC		
Bioassay						**Daphnia**									
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	48 hrLT50 Daphnia	%Mort	na	0.0	0.0	0.00		NC	5	Pass
											0.00		NC		
											0.00		NC		
											0.00		NC		
											0.00		NC		
Bioassay						**Trout**									
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	96hrLC50 Trout	%Mort	na	0.0	0.0	0.00		NC	5	Pass
											0.00		NC		
											0.00		NC		
											0.00		NC		
											0.00		NC		

Resin Fatty Acids						**Abietic Acid**									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Abietic Acid	mg/L	0.0010	0.0043		0.004	0.002	2.1	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Abietic Acid	mg/L	0.0010	0.0037	<0.010	NC	0.002	NC	4	Pass
					WW	Abietic Acid	mg/L				0.000	0.000	NC		
					WW	Abietic Acid	mg/L				0.000	0.000	NC		
						Abietic Acid	mg/L				0.000	0.000	NC		
						Arachidic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Arachidic Acid	mg/L	0.0050	<0.0050	NR	NC	NC	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Arachidic Acid	mg/L	0.0050	<0.0050	NR	NC	NC	NC		
						Arachidic Acid	mg/L				0.000	0.000	NC		
						Arachidic Acid	mg/L				0.000	0.000	NC		
						Arachidic Acid	mg/L				0.000	0.000	NC		
						Behenic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Behenic Acid	mg/L	0.0050		NR	NC	0.007	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Behenic Acid	mg/L	0.0050	<0.0050	NR	NC	NC	NC		
						Behenic Acid	mg/L				0.000	0.000	NC		
						Behenic Acid	mg/L				0.000	0.000	NC		
						Behenic Acid	mg/L				0.000	0.000	NC		
						12-Chlorodehydroabietic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	12-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	12-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	<0.010	NC	NC	NC	4	Pass
					WW	12-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	12-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	12-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
						14-Chlorodehydroabietic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	14-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	14-Chlorodehydroabietic Acid	mg/L	0.0010	<0.0010	<0.010	NC	NC	NC	4	Pass
					WW	14-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	14-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	14-Chlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
						Dehydroabietic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Dehydroabietic Acid	mg/L	0.0010	0.0063	0.0780	0.072	0.002	31.1	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Dehydroabietic Acid	mg/L	0.0010	0.0042	<0.010	NC	0.002	NC	4	Pass
					WW	Dehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	Dehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	Dehydroabietic Acid	mg/L				0.000	0.000	NC		
						Dichlorodehydroabietic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Dichlorodehydroabietic Acid	mg/L	0.0010	<0.0010	NR	NC	NC	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Dichlorodehydroabietic Acid	mg/L	0.0010	<0.0010	NR	NC	NC	NC		
					WW	Dichlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	Dichlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
					WW	Dichlorodehydroabietic Acid	mg/L				0.000	0.000	NC		
						Isopimaric & Palustric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Isopimaric & Palustric Acid	mg/L	0.0030	<0.0030	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Isopimaric & Palustric Acid	mg/L	0.0020	<0.0020	<0.010	NC	NC	NC	4	Pass
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.000	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.000	NC		
					WW	Isopimaric & Palustric Acid	mg/L				0.000	0.000	NC		
						Lauric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Lauric Acid	mg/L	0.0030	<0.0030	<0.0010	NC	NC	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Lauric Acid	mg/L	0.0050	<0.0050	NR	NC	NC	NC		
					WW	Lauric Acid	mg/L				0.000	0.000	NC		
					WW	Lauric Acid	mg/L				0.000	0.000	NC		
					WW	Lauric Acid	mg/L				0.000	0.000	NC		
						Levopimaric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Levopimaric Acid	mg/L	0.0070	<0.0070	0.0190	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Levopimaric Acid	mg/L	0.0040	<0.0040	<0.010	NC	NC	NC	4	Pass
					WW	Levopimaric Acid	mg/L				0.000	0.000	NC		
					WW	Levopimaric Acid	mg/L				0.000	0.000	NC		
					WW	Levopimaric Acid	mg/L				0.000	0.000	NC		
						Lignoceric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Lignoceric Acid	mg/L	0.0050		NR	NC	0.007	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Lignoceric Acid	mg/L	0.0050	<0.0050	NR	NC	NC	NC		
					WW	Lignoceric Acid	mg/L				0.000	0.000	NC		
					WW	Lignoceric Acid	mg/L				0.000	0.000	NC		
					WW	Lignoceric Acid	mg/L				0.000	0.000	NC		
						Linoleic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Linoleic Acid	mg/L	0.0050	0.0580	0.0230	0.035	0.015	2.3	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Linoleic Acid	mg/L	0.0050	0.0471	<0.010	NC	0.014	NC	4	Pass
					WW	Linoleic Acid	mg/L				0.000	0.000	NC		
					WW	Linoleic Acid	mg/L				0.000	0.000	NC		
					WW	Linoleic Acid	mg/L				0.000	0.000	NC		
						Linolenic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Linolenic Acid	mg/L	0.0080	<0.0080	<0.0050	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Linolenic Acid	mg/L	0.0050	<0.0050	<0.010	NC	NC	NC	4	Pass
					WW	Linolenic Acid	mg/L				0.000	0.000	NC		
					WW	Linolenic Acid	mg/L				0.000	0.000	NC		
					WW	Linolenic Acid	mg/L				0.000	0.000	NC		
						Myristic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Myristic Acid	mg/L	0.0050		NR	NC	0.007	NC		
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Myristic Acid	mg/L	0.0050	0.0053	NR	NC	0.008	NC		
					WW	Myristic Acid	mg/L				0.000	0.000	NC		
					WW	Myristic Acid	mg/L				0.000	0.000	NC		
					WW	Myristic Acid	mg/L				0.000	0.000	NC		
						Neoabietic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Neoabietic Acid	mg/L	0.0010	<0.0010	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Neoabietic Acid	mg/L	0.0010	<0.0010	<0.010	NC	NC	NC	4	Pass
					WW	Neoabietic Acid	mg/L				0.000	0.000	NC		

					WW	Neoabietic Acid	mg/L				0.000	0.000	NC		
					WW	Neoabietic Acid	mg/L				0.000	0.000	NC		
						Oleic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Oleic Acid	mg/L	0.0050	0.0270	0.0240	0.003	0.011	0.3	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Oleic Acid	mg/L	0.0050	0.0222	<0.010	NC	0.010	NC	4	Pass
					WW	Oleic Acid	mg/L				0.000	0.000	NC		
					WW	Oleic Acid	mg/L				0.000	0.000	NC		
					WW	Oleic Acid	mg/L				0.000	0.000	NC		
						Palmitic Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Palmitic Acid	mg/L	0.0700	<0.0700	NR	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Palmitic Acid	mg/L	0.0500	<0.050	NR	NC	NC	NC		
					WW	Palmitic Acid	mg/L				0.000	0.000	NC		
					WW	Palmitic Acid	mg/L				0.000	0.000	NC		
					WW	Palmitic Acid	mg/L				0.000	0.000	NC		
						Pimaric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Pimaric Acid	mg/L	0.0010	0.0020	0.0100	0.008	0.002	4.7	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Pimaric Acid	mg/L	0.0010	<0.0010	<0.010	NC	NC	NC	4	Pass
					WW	Pimaric Acid	mg/L				0.000	0.000	NC		
					WW	Pimaric Acid	mg/L				0.000	0.000	NC		
					WW	Pimaric Acid	mg/L				0.000	0.000	NC		
						Sandaracopimaric Acid									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Sandaracopimaric Acid	mg/L	0.0010	<0.0010	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Sandaracopimaric Acid	mg/L	0.0010	<0.0010	<0.010	NC	NC	NC	4	Pass
					WW	Sandaracopimaric Acid	mg/L				0.000	0.000	NC		
Resin Fatty Acids						**Total Fatty Acids**					0.0	0.0			
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Total Fatty Acids	mg/L	0.0100	0.0130	0.1800	0.167	0.016	10.5	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Total Fatty Acids	mg/L	0.0600	0.0750	0.0100	0.065	0.095	0.7	4	Pass
					WW	Total Fatty Acids	mg/L				0.000	0.000	NC		
					WW	Total Fatty Acids	mg/L				0.000	0.000	NC		
					WW	Total Fatty Acids	mg/L				0.000	0.000	NC		
											0.000	0.000	NC		
						Total Resin Acids									
	S1435016484	E103144	QRP Final Discharge	23-Jun-15	WW	Total Resin Acids	mg/L	0.0010	<0.0010	<0.0010	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Total Resin Acids	mg/L	0.0100	<0.010	<0.010	NC	NC	NC	5	Pass
					WW	Total Resin Acids	mg/L				0.000	0.000	NC		
					WW	Total Resin Acids	mg/L				0.000	0.000	NC		
					WW	Total Resin Acids	mg/L				0.000	0.000	NC		
Absorbable Organic Halides (AOX)						**AOX**									
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	Adsorbable Organic Halide	mg/L	NR	NR	<0.006	NC	NC	NC	5	Pass
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	Adsorbable Organic Halide	mg/L				0.00	0.0	NC		
					WW	AOX	mg/L				0.00	0.0	NC		

Metals						Dissolved								
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Hardness	mg/l	0.5	203	194	9.00	29.4	0.3	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Aluminum	mg/l	0.0020	0.1160	0.083	0.03	0.0	1.7	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Antimony	mg/l	0.0002	<0.00020	<0.0002	NC	NC	NC	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Arsenic	mg/l	0.0002	0.0025	0.0026	0.00	0.0	0.2	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Barium	mg/l	0.0001	0.2320	0.2030	0.03	0.0	0.9	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Beryllium	mg/l	0.0002	<0.00020	0.00002	NC	NC	NC	5	Pass
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Bismuth	mg/l	0.0001	0.0001	NR	NC	0.0	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Cadmium	mg/l	0.00001	0.00433	0.00400	0.00033	0.00063	0.5	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Calcium	mg/l	0.1000	45.1000	42.90000	2.20	6.5	0.3	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Chromium	mg/l	0.0002	0.0080	0.00550	0.0025	0.0014	1.8	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Colbalt	mg/l	0.0002	0.0009	0.00077	0.00009	0.00040	0.2	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Copper	mg/l	0.0004	0.0178	0.01620	0.0016	0.0031	0.5	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Iron	mg/l	0.0100	0.1470	0.14400	0.00	0.0	0.1	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Lead	mg/l	0.0001	0.0116	0.01250	0.00	0.0	0.5	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Lithium	mg/l	NR	NR	0.00730	NC	NC	NC	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Magnesium	mg/l	0.0100	22.0000	21.00000	1.00	3.1	0.3	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Manganese	mg/l	0.0002	3.7700	3.49000	0.28	0.5	0.5	4	Pass
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Mercury	mg/l		NR	NR	NC	NC	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Molybdenun	mg/l	0.0001	0.00167	0.00079	0.00088	0.00038	2.3	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	Nickel	mg/l	0.0010	0.00510	0.00490	0.00020	0.00214	0.1	5	Pass

	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Phosphorous**	mg/l	0.0200	0.77100	NR	NC	0.14	NC		
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Potassium**	mg/l	0.1000	21.50	18.90	2.60	3.2	0.8	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Selenium**	mg/l	0.0001	0.00016	<0.00050	NC	0.0	NC	4	Pass
	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Silicon**	mg/l	0.1000	32.00	NR	NC	4.7	NC	0	
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Silver**	mg/l	0.000020	0.000022	<0.000020	NC	0.0	NC	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Sodium**	mg/l	0.100000	671.00	627.00	44.00	95.0	0.5	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Strontium**	mg/l	0.00040	0.244	0.35600	0.11	0.0	3.2	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Sulphur**	mg/l	1.000	133.00	132.00	1.00	20.2	0.0	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Thallium**	mg/l	0.00002	0.000082	0.00015	0.00007	0.00004	1.7	0	Fail
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Tin**	mg/l	0.00020	0.00310	0.00300	0.00010	0.00072	0.1	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Titanium**	mg/l	0.00060	0.00361	0.00860	0.0050	0.0014	3.7	0	Fail
												0.0			
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Uranium**	mg/l	0.000020	0.002670	0.00277	0.00010	0.00041	0.2	5	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Vanadium**	mg/l	0.0010	0.0095	0.00800	0.0015	0.0028	0.5	4	Pass
18.1	S1520973847	E103144	QRP Final Discharge	20-Mar-18	WW	**Zinc**	mg/l	0.0020	0.3910	0.37900	0.01	0.1	0.2	5	Pass

Metals						**Total**									
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Aluminum**	mg/l	0.0060	0.2190	0.2020	0.0170	0.0395	0.4	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Antimony**	mg/l	0.0002	0.0003	<0.00050	NC	0.0	NC	4	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Arsenic**	mg/l	0.0002	0.0027	0.0025	0.00019	0.00066	0.3	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Barium**	mg/l	0.0001	0.2830	0.2220	0.0610	0.0402	1.5	2	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Beryllium**	mg/l	0.0002	<0.00020	<000050	NC	NC	NC	4	Pass
		E103144	QRP Final Discharge	20-Mar-18	WW	**Bismuth**	mg/l	0.0001	0.0001	NR	NC	0.0	NC		
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Boron**	mg/l	0.0200	0.0290	0.0230	0.0060	0.0324	0.2	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Cadmium**	mg/l	0.00001	0.00501	0.0039	0.00111	0.00072	1.5	2	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Calcium**	mg/l	0.1000	47.7000	45.4000	2.30	6.9	0.3	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Chromium**	mg/l	0.0002	0.0101	0.0086	0.0015	0.0017	0.9	4	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Colbalt**	mg/l	0.0002	0.0010	0.0010	0.0000	0.0004	0.0	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Copper**	mg/l	0.0010	0.0217	0.0180	0.0037	0.0045	0.8	4	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Iron**	mg/l	0.0100	0.2300	0.2880	0.0580	0.0467	1.2	2	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Lead**	mg/l	0.0001	0.0130	0.0105	0.0025	0.0020	1.3	2	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Magnesium**	mg/l	0.0100	20.4000	21.7000	1.3000	2.8991	0.4	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Manganese**	mg/l	0.0002	3.6000	3.5000	0.1000	0.5094	0.2	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Molybdenum**	mg/l	0.0001	0.0025	0.0027	0.0002	0.0005	0.5	4	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Nickel**	mg/l	0.0010	0.0058	0.0050	0.0008	0.0022	0.4	5	Pass
		E103144	QRP Final Discharge	20-Mar-18	WW	**Phosphorous**	mg/l	0.0600	3.2900	NR	NC	0.5501	NC		
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Potassium**	mg/l	0.1000	20.8000	19.8000	1.0000	3.0830	0.3	5	Pass

18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Selenium**	mg/l	0.0001	0.0004	<0.00050	NC	0.0002	**NC**	4	Pass
		E103144	QRP Final Discharge	20-Mar-18	WW	**Silicon**	mg/l	0.2000	33.9000	NR	NC	5.0770	**NC**		
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Silver**	mg/l	0.0000	0.0004	0.0003	0.00012	0.00008	1.5	2	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Sodium**	mg/l	0.1000	700.0000	733.0000	33.0000	99.1364	0.3	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Strontium**	mg/l	0.0004	0.2750	0.3060	0.0310	0.0395	0.8	4	Pass
		E103144	QRP Final Discharge	20-Mar-18	WW	**Sulphur**	mg/l	1.0000	143.0000	NR	NC	21.6375	**NC**		
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Thallium**	mg/l	0.0000	0.00014	0.00014	0.000003	0.000048	0.1	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Tin**	mg/l	0.0002	0.0027	0.0026	0.00002	0.00066	0.0	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Titanium**	mg/l	0.0006	0.0035	0.0130	0.0096	0.0013	**7.1**	0	Fail
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Uranium**	mg/l	0.0000	0.0036	0.0035	0.0001	0.0005	0.2	5	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Vanadium**	mg/l	0.0010	0.0142	0.0120	0.0022	0.0034	0.6	4	Pass
18.1		E103144	QRP Final Discharge	20-Mar-18	WW	**Zinc**	mg/l	0.0060	0.4030	0.3970	0.01	0.1	0.1	5	Pass

Notes:

Interpretive Notes:

1. The **Points Assigned** (Column O) are based on an industry standard grading scale. Available points are 5, 4, 2 and 1 (5 is the highest possible score). Scores of 0 and 2 demonstrate an unacceptable analytical result.

Key Notes:

NC : Not Completed or Not Calculable. NC denotes that a test result was either '*Not Reported*' of was '*Reported Below the Reportable Detection Limit (RDL)*'.

2.1 Column N Cells that are highlighted dark green and boldened indicate results that deviate by a factor of 2 or greater or those that are categorized as NC. Cells with this designation require further scrutiny.

NC Column N Cells that are highlighted dark green and boldened and contain 'NC' require further scrutiny. These test results may not be valid, or the difference between a 'below detect' and a detect may be great enough to warrant further investigative actions.

na : not applicable

NR : Not Reported

% Mort: Percent of mortality among test organisms which occurred during the full test period of an LC50 or LT50 bioassay.

NAL : Not Acutely Lethal which is designated for a Lethal Concentration LC50 biassay test that did not result in a 50% mortality of test organisms during the 96 or 48 hour testing period.

For more information please contact Ministry of Environment and Climate Change Strategy, Laboratory Services: 4th Floor - 525 Superior Street, Victoria, BC V8V 1T7 Phone: 778.698.4411

Client Name:	**Quesnel River Pulp**
Audit No.:	**18.1**
Requisition No.:	**S1520973847**
Sample Date:	**20-Mar-18**
Total Tests Included:	**90**
Total Points Assigned:	**355**
Failed Test Results:	**14**
Percent of Failed Tests:	**16%**
Performance Evaluation:	**79%**
Audit Result:	**PASS**

To evaluate an audit enter the Requisition No. and Sample Date into cells C5 and C6 above (or copy and paste from the 'Data Results' page). The values for i.e. Total Tests Included or Percent of Failed Tests are produced automatically by functions.

To pass an audit your percent of failed tests cannot exceed 25% and your performance score must be 70 or higher.

Appendix A – R.M. Young 5305 Analysis Data (2013-2017)

Unit (S/N)	Date	Azimuth (º)	Vane Torque (g/cm)	Speed (m/s)	Propeller Torque (g/cm)	Station	Notes
23027	Oct-13	1	33	0.004	2.1	Kelowna College	
29021	Oct-13	2	7	0.002	0.5	Audit Lab	
29022	Oct-13	3.7	36	0.002	0.5	Telkwa	
29051	Oct-13	2.5	35	-0.002	0.4	Quesnel	
40716	Oct-13	2.8	18	0.004	0.8	Quesnel - Linden	
40724	Oct-13	7.7	30	0.004	12.8	PG Pulp	
40725	Oct-13	13.5	24	0.004	1.1	Qualicum	
44324	Oct-13	3.2	21	0.004	0.5	Grand Forks	
45091	Oct-13	1.6	30	0.004	2.8	Kamloops Brokelhurst	
50201	Oct-13	3.8	18	0.004	0.7	Houston	
50202	Oct-13	2.7	39	0.004	0.7	Glendale	4000 RPM not used?
50220	Oct-13	2	27	0.004	1.6	Quesnel SS	
61870	Oct-13	4.2	5	0.004	0.4	unknown	
99211	Oct-13	2.3	22.5	0.004	0.4	Esquimalt	
105494	Oct-13	2.7	55	30.72	18.2	Williams Lake Canadian Tire	Bearing too worn out to test
105496	Oct-13	2.7	17.5	0.004	0.5	Smithers	
40718	Sep-14	2	60	0.004	0.5	Burns Lake	
40719	Sep-14	1.6	36	0.004	0.4	Terrace	
40720	Sep-14	3.3	45	0.004	0.5	New Hazleton	
49000	Sep-14	1	18	0.004	2.9	Warfield	
50215	Oct-14	1.1	26	0.004	0.4	Golden - Lady Grey School	
50216	Oct-14	3.07	32	0.9	0.4	Creston - PC School	
57732	Oct-14	1.9	9	0.004	0.4	Kitwanga	
68197	Oct-14	3.7	15	0.004	2.2	Birchbank	
68198	Apr-14	3.2	29	0.004	0.6	Prince Rupert	

						Roosevelt School	
105496	Oct-14	2.8	11	0.004	0.5	Stewart Youth Custody	
112577	Oct-14	0.9	12	0.004	0.7	Squamish	
40721	Jul-15	315.9	19	0.004	0.6	Ucluelet	Returned from field damaged
45657	Jul-15	3.3	33	0.004	0.5	Vernon	
49061	Jul-15	2.2	25	0.004	0.9	unknown	
50223	Jul-15	1.4	38	0.004	0.6	PG Plaza	
57734	Jul-15	3	57	0.00712	1.19	Courtenay Elementary	
61870	Jul-15	3.9	7	0.004	0.4	unknown	
35215	Oct-15	1.1	27	0.004	0.4		
40717	Oct-15	340	23	0.004	0.5	Vanderhoo f Courthouse	No as found azimuth readings
57731	Oct-15	3.68	37	0.004	0.4	Houston	
53124	Oct-15	3	16	0.004	0.5	Valemont	
61862	Oct-15	2.6	11	0.004	0.5	Telkwa	
61863	Oct-15	2	35	0.004	0.7	Gladstone	
61869	Oct-15	2.83	15	0.004	0.8	Duncan	
61870	Oct-15	4.5	7	0.004	0.4		Cross-vandor check with BJB and CSI?
90084	Oct-15	3.6	50	30.72	5.4	Topaz	Internal mechanism s damaged
105496	Oct-15	2.5	21	0.004	0.4	Prince Rupert Roosevelt School	
40716	Mar-16	3	21	0.004	0.5	Creston - PC School	
40716	Mar-17	340	10	0.004	0.5	Vanderhoo f Courthouse	no azimuth response (suspect lightning)
49000	Mar-17	1.2	16	0.004	0.4	Terrace Skeena Middle School	

49061	Mar-17	340	14	0.004	0.7	Vanderhoo f Courthouse	no azimuth response (suspect lightning)
50201	Nov-17	2.1	25	0.004	0.4	Burns Lake	
50220	Mar-17	0.9	47.5	0.004	2.1	Golden - Lady Grey School	
55415	Mar-17	1.43	21	0.004	1.6	unknown	
57733	Mar-17	2.3	35	0.004	2.4	Merritt Parcel St	

(Wiederick, 2017)

Appendix B – Temperature and Humidity Probe Sensor Analysis Data

Date	Make	Model	S/N	Findings	RH error (%)				Temperature Error (°C)				Notes
					~25	~50	~75	MAX	24	24	24	MAX	
21-Oct-13	Vaisala	HMP45C	A4910015	Within Tolerance	-0.6	-2	-1.8	2.00	-0.2	-0.2	-0.2	0.2	
21-Oct-13	Vaisala	HMP45C	C2994	Within Tolerance	-0.4	-0.9	-1.1	1.10	0.1	0.1	0.1	0.1	
21-Oct-13	Vaisala	HMP45C	C2295	Within Tolerance	-0.8	-1.4	-1.5	1.50	-0.1	-0.1	-0.1	0.1	
24-Oct-13	Vaisala	HMP45C	8037	Out of Tolerance	-2.6	-4.6	-4.7	4.70	0.2	0.2	0.2	0.2	
24-Oct-13	Vaisala	HMP45C	8079	Within Tolerance	-0.1	-1	-1	1.00	0.2	0.2	0.2	0.2	
24-Oct-13	Vaisala	HMP45C	8083	Within Tolerance	-0.5	-1.3	-1.1	1.30	0.1	0.1	0.1	0.1	
24-Oct-13	Vaisala	HMP45C	9016	Within Tolerance	-0.2	-1.1	-0.9	1.10	0.1	0.1	0.1	0.1	
24-Oct-13	Vaisala	HMP45C	9025	Within Tolerance	-0.7	-0.7	0	0.70	0.2	0.2	0.2	0.2	
24-Oct-13	Vaisala	HMP45C	9026	Within Tolerance	-0.2	-0.3	0	0.30	0.0	0.0	0.0	0.0	
24-Oct-13	Vaisala	HMP45C	9027	Within Tolerance	-0.3	-1	-1.1	1.10	0.0	0.0	0.0	0.0	
24-Oct-13	Vaisala	HMP45C	10013	Within Tolerance	-0.3	-0.5	0.1	0.50	0.1	0.1	0.1	0.1	
24-Oct-13	Vaisala	HMP45C	10014	Within Tolerance	-0.9	-1.7	-1.7	1.70	0.2	0.2	0.2	0.2	
24-Oct-13	Vaisala	HMP45C	10015	Within Tolerance	0.1	0	-0.1	0.10	0.0	0.0	0.0	0.0	
24-Oct-13	Vaisala	HMP45C	10016	Within Tolerance	-0.7	-1.4	-1.6	1.60	0.0	0.0	0.0	0.0	
24-Oct-13	Vaisala	HMP45C	10067	Within Tolerance	-1.1	-1.4	-0.9	1.40	0.0	0.0	0.0	0.0	
24-Oct-13	Vaisala	HMP45C	12252	Within Tolerance	-0.3	-0.7	-0.5	0.70	-0.2	-0.2	-0.2	0.2	
02-Feb-15	Vaisala	HMP45C	8038	Within Tolerance	-1.4	-1.5	-1.3	1.50	0.2	0.2	0.2	0.2	
02-Feb-15	Vaisala	HMP45C	8002	Out of Tolerance	-1.3	-2.7	-2.8	2.80	0.1	0.1	0.1	0.1	
02-Feb-15	Vaisala	HMP45C	8006	Out of Tolerance	-1.1	-1.9	-2.3	2.30	0.1	0.1	0.1	0.1	
02-Feb-15	Vaisala	HMP45C	8007	Within Tolerance	-0.4	-1.1	-1.5	1.50	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	8034	Out of Tolerance	0.7	-2.8	-3	3.00	0.2	0.2	0.2	0.2	
02-Feb-15	Vaisala	HMP45C	8035	Out of Tolerance	-1.5	-3.4	0.8	3.40	0.1	0.1	0.1	0.1	
02-Feb-15	Vaisala	HMP45C	8038	Within Tolerance	-1.4	-1.5	-1.3	1.50	0.2	0.2	0.2	0.2	
02-Feb-15	Vaisala	HMP45C	8039	Within Tolerance	-0.4	-1.2	-1.2	1.20	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	8078	Within Tolerance	-0.6	-1	-0.9	1.00	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	8082	Within Tolerance	-0.1	-0.7	-0.7	0.70	-0.1	-0.1	-0.1	0.1	
02-Feb-15	Vaisala	HMP45C	8084	Within Tolerance	-0.6	-1.6	-1.7	1.70	-0.3	-0.3	-0.3	0.3	
02-Feb-15	Vaisala	HMP45C	8085	Within Tolerance	-0.4	-0.8	-1	1.00	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	8086	Within Tolerance	-0.5	-0.6	-2.2	2.20	0.2	0.2	0.2	0.2	
02-Feb-15	Vaisala	HMP45C	9030	Within Tolerance	-1.4	-0.8	-1.7	1.70	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	10017	Out of Tolerance	-2	-3.4	-3.7	3.70	0.0	0.0	0.0	0.0	
02-Feb-15	Vaisala	HMP45C	C3076	Within Tolerance	-0.8	-1.4	-1.2	1.40	-0.2	-0.2	-0.2	0.2	
02-Feb-15	Vaisala	HMP45C	C3370	Within Tolerance	-1.5	-2	-1.7	2.00	-0.1	-0.1	-0.1	0.1	
02-Feb-15	Vaisala	HMP45C	C3371	Out of Tolerance	-1.7	-2.3	-2.5	2.50	-0.2	-0.2	-0.2	0.2	
02-Feb-15	Vaisala	HMP45C	x1110005	Within Tolerance	0.1	0.2	0	0.20	-0.3	-0.3	-0.3	0.3	
23-Sep-15	Vaisala	HMP45C	8005	Within Tolerance	-0.3	-0.7	-1	1.00	-0.2	-0.2	-0.2	0.2	

23-Sep-15	Vaisala	HMP45C	8081	Within Tolerance	-0.6	-1	-0.9	1.00	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	9016	Within Tolerance	0.4	0.2	0.3	0.40	-0.2	-0.2	-0.2	0.2	
23-Sep-15	Vaisala	HMP45C	9024	Within Tolerance	-0.6	-1	-1.4	1.40	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	10012	Within Tolerance	-0.4	-0.6	-1.3	1.30	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	10016	Within Tolerance	-0.2	-0.9	-0.9	0.90	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	10018	Within Tolerance	-0.2	-0.9	-1.1	1.10	0.2	0.2	0.2	0.2	
23-Sep-15	Vaisala	HMP45C	11126	Within Tolerance	-0.5	-1	-1.2	1.20	-0.2	-0.2	-0.2	0.2	
23-Sep-15	Vaisala	HMP45C	C3075	Out of Tolerance	-0.6	-1.6	-2.4	2.40	-0.1	-0.1	-0.1	0.1	
23-Sep-15	Vaisala	HMP45C	C3369	Within Tolerance	-0.2	-0.9	-1.3	1.30	0.2	0.2	0.2	0.2	
23-Sep-15	Vaisala	HMP45C	C12178	Within Tolerance	-1.1	-1.7	-2	2.00	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	C12179	Out of Tolerance	-1.1	-2.3	-2.8	2.80	0	0	0	0.0	
23-Sep-15	Vaisala	HMP45C	W3820005	Within Tolerance	-1	-0.6	0.5	1.00	-0.2	-0.2	-0.2	0.2	
23-Sep-15	Vaisala	HMP45C	x1110012	Within Tolerance	0	0	0.1	0.10	-0.3	-0.3	-0.3	0.3	
					changed expected temperature -->				**23**	**23**	**23**		
26-May-17	Vaisala	HMP45C	8008	Within Tolerance	-0.1	0	-0.3	0.30	-0.2	-0.2	-0.2	0.2	
26-May-17	Vaisala	HMP45C	8036	Within Tolerance	0.6	0.8	0.7	0.80	-0.1	0.0	0.0	0.1	
26-May-17	Vaisala	HMP45C	8079	Within Tolerance									no as-found data; stated to be within tolerance
01-Jun-17	Rotronic	HC2-S3	61012285	Out of Tolerance	2.5	3	2	3.00	0.0	0.0	0.0	0.0	
01-Jun-17	Vaisala	HMP45C	8084	Within Tolerance	0	0.5	0	0.50	0.2	0.2	0.2	0.2	
01-Jun-17	Vaisala	HMP45C	8085	Within Tolerance	-0.1	0	-0.4	0.40	0.1	0.2	0.2	0.2	
01-Jun-17	Vaisala	HMP45C	8086	Within Tolerance	0.3	0.6	0.3	0.60	0.2	0.1	0.1	0.2	
01-Jun-17	Vaisala	HMP45C	9028	Within Tolerance	-1.2	-1.4	-1.6	1.60	0.2	0.1	0.2	0.2	
01-Jun-17	Vaisala	HMP45C	10015	Within Tolerance	-0.4	-0.6	-0.8	0.80	0.1	0.0	0.1	0.1	
01-Jun-17	Vaisala	HMP45C	10017	Within Tolerance	-0.1	-0.2	-1.2	1.20	0.0	0.0	0.0	0.0	
01-Jun-17	Vaisala	HMP45C	10020	Out of Tolerance	0.1	0.4	0.3	0.40	0.3	0.3	0.3	0.3	
01-Jun-17	Vaisala	HMP45C	10065	Within Tolerance	-0.5	-0.1	-0.3	0.50	-0.1	-0.1	-0.1	0.1	
01-Jun-17	Vaisala	HMP45C	12252	Within Tolerance	-0.3	-0.3	-0.8	0.80	0.1	0.1	0.0	0.1	
01-Jun-17	Vaisala	HMP45C	C2996	Out of Tolerance	-0.8	-1.3	-2.2	2.20	-0.1	-0.1	-0.1	0.1	
01-Jun-17	Vaisala	HMP45C	C3371	Within Tolerance	-0.5	-1.1	-1.7	1.70	0.1	0.1	0.1	0.1	
01-Jun-17	Vaisala	HMP45C	C12180	Out of Tolerance	-0.4	0.1	0	0.40	-0.3	-0.3	-0.3	0.3	
01-Jun-17	Vaisala	HMP45C	C12181	Within Tolerance	-0.6	-1.5	-0.6	1.50	0.0	-0.1	0.0	0.1	
01-Jun-17	Vaisala	HMP45C	C12183	Within Tolerance	-1.2	-0.5	-1.6	1.60	-0.1	0.0	0.0	0.1	

Appendix C – Station Siting Characteristics (Wiederick, 2017)

No.	Station	Station Type	Climate site (Y/N)	Ambient Logger Type	Met Logger Type	Probe Type	Wind Sensor	Pluvio (Y)	Snow Depth (Y)	Potential for Integration (Y/N)	Building & Tower Heights	Urban Climate Zone	Spacing	Notes
1	Ainsworth 100 Mile House	Climate	Y	-	CR1000	HMP45HSP	-	Y	Y	N	N/A			Site will likely be shut down.
2	Burns Lake Fire Centre	Hot Spot		Envidas Ultimate	23x	HMP45HSP	05305			Y	10 m tower on roof			Not visible on google street view/google earth.
3	Colwood	Core		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tower	5 – 6 – residential with municipal hall/works.	75 m N – slopes uphill to tall trees and low density residential housing. Immediate area large well separated buildings.	Site being installed for one year. Station and tower within UCL: beside large city hall building in open area surrounded by residential, in bowl (closest houses could be taller than tower height).
4	Courtney Elementary School	Core		Envidas Ultimate	CR1000	HMP45C	05305			Y	10 m tower	5 – residential with school.	Houses spaced ~4 m-8. 30-40 m across streets. Lots of tress infilling.	No siting meta-data on station start-up form. In school field. Measured from tower: 20m to NE – houses; 30m to SE – large trees (30m+); 70m NW portable school building; 120m SW to large school (2 stories). Surrounded by low density suburban housing.
5	Cranbrook	Core		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tower	5 - 6	Houses spaced ~4 m- 30 m across streets.	Site not yet installed. Surrounded by 1-2 story residential and park Measured from tower: 90m to NE large stand of trees spanning 50°; 100 E large building (peaked roof – estimate 3 stories); 180m of park to N, SSE → NNW single family residential.
6	Duncan Open Learning Centre	Core		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tower	5 – 6 → difficult to classify as there are several converging zones (4,5,6). 20-30 m across streets, between major buildings.	Highly variable due to changing land use types in close proximity.	On gravel parking area: 100 m N residential; 25m NNE to school field, 100 m NE→ SE residential. Within 30 m of school buildings (2-3 stories), commercial buildings (grocery store, gas station). Area has many stands of tall trees. 15m SW large building (school gym), tall trees (30m+) in vectors 170-250°. 30 m W green space, 100 m W multi-family residential 4 stories).
7	Farmington	Special Project		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tower			Need to confirm new location.
8	Golden Lady	Hot Spot		-	21x	HMP45C	05305			N	10 m tilt	5 –	Houses closely spaced	Surrounded by closely spaced 1-2

	Grey School										pole on single story school roof ~70m diagonal.	residential with school.	~4 m. 20-30m across streets.	story residential. Houses 50 m N, 70 m E, 80 m S, 120 m W across school field. Development Homogenous except for school; Hospital 250 m NE. School single story, steps up at gymnasium 19 m E. Sporadic tall trees 10-15 m
9	Grand Forks Airport	Hot Spot	Y	-	23x	HMP45C	05305	Y	Y	N	10 m tower	7 – though at small airport.	80 m N from 2 story house; 30 m N from 2-3 m trees	Rural with small airport: ~220 m N small terminal, airport out-buildings surrounded largely by open field (single runway). Further N industrial park. All other directions rural farmland, very low density housing.
10	Houston Fire hall	Hot Spot		Envidas Ultimate	23x	HMP45C	05305			Y	10 m roof-top tower; 17m diagonal	5	10-30 m between buildings.	Google street view unavailable. Land use seems to be low-density commercial (1-2 stories) spaced 10-30 m apart. School field 75m to SE. Few trees in any direction.
11	Kelowna College	Core		Envidas Ultimate	CR1000	HMP45C	05305			Y	Need tower location.			Need precise tower location on campus.
12	Merritt Parcel Street			Envidas Ultimate	CR1000	HMP45C	05305			N	10 m tower	5		North – 6 m to single story house. Fence-line for RV park 5m South. Land use changes quickly from residential to heavy industrial to the E (sawmill 330 m E). School yard 110 m W.
13	Prince George Glenview School			-	21x	HMP45C	05305			N	10 m tower on school gym (2 stories); 27m diagonal.	5 to the W; Dense mature forest (20-30 m trees) 90m west)	10-40 m, but lots of large trees infilling between houses.	Dense forest to the W; N,E,S, low density residential with lots of large trees between buildings (~10 m tall).
14	Prince George Plaza	Core		Envidas Ultimate	CR1000	HMP45C	05305			Y	7 m tower on E edge of 7 story L-shaped building w/ ~90m diagonal.	2	Closely spaced downtown core.	Somewhat anomalously tall building in area – building heights variable – lots of 1-2 story buildings.
15	Prince George Pulp			-	21x	HMP45C	05305			N	10 m tower on lower section of major warehouse roof; 131m diagonal, ~10 m tall.	Does not fit classification scheme		Start-up form states purpose to determine direction of mill emissions. In major industrial area with spaced out large infrastructure (pulp mill), and large open spaces.

16	Prince Rupert Roosevelt Park			-	21x	HMP45C	05305			N	10 m tilt pole. Roof 63 m diagonal along length, 31m diagonal along width.	6, though complicated with tree coverage.	Dense trees then typical residential housing spacing.	On two-story school roof. Trees to N and E are at about roof height. School near summit on hill. Small stand of tall trees to the S bordering school to small field. Approx. 100 m to low density residential with tall trees. Hospital about 240 m S (up to 6 stories, but looks to be lower than topography and trees to the N. Tall trees to the W. Mostly low density residential on slope below the school/hospital. Coastal town against large mountains.
17	Quesnel CP			-	21x	HMP45C	05305			N	Need precise location.	Does not fit classification scheme		Not viewable on Google Earth/street view. Start-up form: initiated to understand wind and temperatures at low elevations in the valley and for modelling – noted it could be temporary in 1993.
18	Quesnel Senior Secondary	Core		Envidas Ultimate	23x	HMP45C	05305			Y	10 m tilt pole on school roof. On large two story section approx. 130 m diagonal.	5; 4 300m to SW.	10-30 m between buildings.	Used to differentiate particulate from multiple sources. School field stretching 130 m N from school. School building to 150 m S of tower. Typical low density residential surrounds school with a few 3-4 story apartments 90 m W. Transitions to commercial 300 m SW.
19	Smithers St. Josephs	Core		Envidas Ultimate	21x	HMP45C	05305			Y	15 m free standing tower.	5	10-40 m between buildings.	Located beside predominantly 1 story school in low density residential area with Commercial 300 m SE and 475m NE. Approx. 15 m from ~15 m+ trees to the N, a few more 40 m NW Church with tall steeple 60 m S of tower.
20	Squamish Elementary	Core		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tilt pole on ground	6 at schools, transitions to 5 and 4 in immediate vicinity.	Highly variable due to changing land use.	Site relatively new – not viewable on Google Earth. Mostly commercial and multi-family residential 200 m SE→SW. River than forest 300 m to E. 200 m NNW of school Church and High School, then forest. Small residential area 200 m NW.
21	Stewart Youth Centre			-	21x	HMP45C	05305			N	10 m tilt pole on roof 45 m diagonal.	5-6 – very low density	Houses spaced 10-40 m. Much less dense then typical residential. Dense forest 13 0m E, then large river.	Unable to view on Google Street View – very low density residential. Lots of 10-20 m+ trees in area with widely spaced housing. Large building 50 m NE. Closest house 50

														m W (need to confirm precise location – tower not visible on Google Earth).
22	Telkwa			-	23x	HMP45C	05305			N	10 m free standing tower	5 – very low density	Houses spaced 10-40 m. Much less dense then typical residential.	Trees to the N; NW; W; exposure largely open in other directions (sports field). Low density residential N and S.
23	Terrace Skeena Middle School	Core		Envidas Ultimate	CR1000	HC2-S3	05305			Y	10 m tower attached to station.	5	Typical residential spacing with lots of 10-20m+ trees infilling between houses	Not viewable from Google Earth – need exact tower location. School 2 stories. School has large playing fields 100 m N, 150 m W. Parking lot then grass 90 m E; residential housing 50 m S. Standard suburban development in all directions; other schools 250 m N and 300 m NE.
24	Valemount Courthouse	Environmental Impact Monitoring		-	21x	HMP45C	05305			N	10 m tower on roof.			Not viewable from Google Earth or street view. Need precise location and building height.
25	Vanderhoof Courthouse	Hot Spot		-	CR1000	HMP45C	05305			N	10 m tilt-pole on roof of single story building. 30m diagonal.	4 transitioning to 5 (small community)	Mostly 1-2 story commercial buildings. Spaced 10-50 m apart.	School 100 m N, 13 m E another large single-story building (60m x 15m). Main roof 35 m diagonal. Commercial to the S and W. Residential 220 m NE, 110m NW, 440 m E.
26	Vernon Science Centre	Core		Envidas Ultimate	CR1000	HMP45C	05305			Y	~ 6 m pole on roof of 2-3 story building with pitched roof	On border of 4/5.	Dense commercial in areas N. On border between UCZ – spacing highly variable.	Lower-rise buildings 45 m diagonal attached to main building. On border of UCZ 4 running 1km N. Park w/ trees/playing field 350 m S, then hospital. Predominantly residential to NE and SW
27	Victoria Topaz	Core		Envidas Ultimate	21x	HMP45C	05305			N	10 m tower on large extension of school (90m diagonal).	On border of 2/3.	Dense commercial in areas E. On border between UCZ – spacing highly variable.	2-4 story multifamily housing 150 m E, transitions to single family residential after ~200 m. Park 200 m S, 550 m N. Highly developed urban E of station; 2-story school building surrounded by tightly spaced trees - some at or above roof height.
28	Williams Lake Columneetza	Core	Y	Envidas Ultimate	CR3000	HC2-S3	05305	Y	Y	Y	10 m tower to be installed	5	10-30 m between buildings; large trees to east.	Surrounded by UCZ 5 ~500 m radius; in school field. Site bordered by 10-15 m trees approx. 30 m W. Two-story school 60 m NW.

(Wiederick, 2017)

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**															
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004	
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg	
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	
2018-05-10 15:20	0																			
2018-05-10 15:40	1																			
2018-05-10 16:00	2																			
2018-05-10 16:20	3																			
2018-05-10 16:40	4																			
2018-05-10 17:00	5																			
2018-05-10 17:20	6																			
2018-05-10 17:40	7																			
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2018-05-10 18:20	9																			
2018-05-10 18:40	10																			
2018-05-10 19:00	11																			
2018-05-10 19:20	12																			
2018-05-10 19:40	13																			
2018-05-10 20:00	14																			
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2018-05-10 21:40	19																			
2018-05-10 22:00	20																			
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2018-05-11 8:20	51																			
2018-05-11 8:40	52																			
2018-05-11 9:00	53																			
2018-05-11 9:20	54	1.771	25.95	161	22.27	1.964	1.958	25.53	164.5	163.714	22.01	1.956	26.77	158.2	23.4	1.858	30.87	159.6	23.86	
2018-05-11 9:40	55	2.076	26.9	168.7	23.21	2.307	2.300	25.9	170.5	169.686	22.89	2.253	27.71	166.3	24.25	2.153	30.07	166.8	24.37	
2018-05-11 10:00	56	1.884	25.67	163.2	22.63	2.079	2.072	31.62	165.1	164.311	24.83	2.042	32.61	159.8	25.66	1.969	32.23	161.1	25.34	
2018-05-11 10:20	57																			
2018-05-11 10:40	58																			
2018-05-11 11:00	59																			
2018-05-11 11:20	60																			
2018-05-11 11:40	61																			
2018-05-11 12:00	62																			
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2018-05-11 14:00	68																			
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2018-05-11 21:20	90																			
2018-05-11 21:40	91																			
2018-05-11 22:00	92																			
2018-05-11 22:20	93																			
2018-05-11 22:40	94																			
2018-05-11 23:00	95																			

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**														
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc
2018-05-11 23:20	96																		
2018-05-11 23:40	97																		
2018-05-12 0:00	98																		
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2018-05-12 7:40	121																		
2018-05-12 8:00	122																		
2018-05-12 8:20	123																		
2018-05-12 8:40	124	1.312	66.31	111.8	51.84	1.505	1.500	66.64	107.4	106.887	52.27	1.514	66	106.9	52.24	1.451	65.32	107.5	51.47
2018-05-12 9:00	125	1.637	39.49	155.2	32.51	1.845	1.839	36.82	157.9	157.146	31.5	1.829	37.91	154.4	32.4	1.756	38.79	153.4	32.45
2018-05-12 9:20	126	1.541	39.53	133.6	34.12	1.776	1.770	37.72	135.7	135.052	33.36	1.778	40.28	133	34.1	1.697	41.57	132.4	34.4
2018-05-12 9:40	127	1.768	27.64	146.4	22.59	2.037	2.031	25.69	147.5	146.795	22.26	2.011	27.14	144.2	22.12	1.907	30.19	144.3	23.77
2018-05-12 10:00	128	1.29	54.01	111.2	44.82	1.506	1.501	57.42	110.9	110.370	47.37	1.515	55.97	108.7	46.3	1.404	57.57	107.7	45.69
2018-05-12 10:20	129	1.477	46.45	146.9	34.28	1.75	1.744	47.91	149.2	148.487	34.81	1.762	48.63	146.1	36.12	1.633	50.9	144.5	35.43
2018-05-12 10:40	130	1.855	42.69	134.9	34.96	1.994	1.988	43.99	137.8	137.142	35.53	2.013	44.64	133.6	36.18	1.967	45.23	133.9	35.94
2018-05-12 11:00	131	1.836	37.96	146.5	32.12	2.042	2.035	37.87	148.7	147.990	32.56	2.056	38.97	145.3	33.13	1.961	41.24	145	33.19
2018-05-12 11:20	132	1.632	32.14	155.2	27.58	1.848	1.842	34.14	157.2	156.449	29.59	1.869	34.11	153	29.27	1.753	36.5	153	29.77
2018-05-12 11:40	133	1.427	36.74	164.1	29.08	1.611	1.606	38.32	165.5	164.709	31.41	1.621	40.42	161.6	31.34	1.528	41.97	162	31.34
2018-05-12 12:00	134	1.581	37.8	168.1	29.86	1.729	1.723	37.71	171.1	170.283	31.11	1.757	37.65	167.4	30.61	1.666	39.3	167.1	31.13
2018-05-12 12:20	135																		
2018-05-12 12:40	136																		
2018-05-12 13:00	137																		
2018-05-12 13:20	138	1.55	30.63	165.5	20.86	1.684	1.679	39.06	167.5	166.700	24.68	1.768	37.67	164.6	24.63	1.63	40.29	163.8	25.07
2018-05-12 13:40	139																		
2018-05-12 14:00	140																		
2018-05-12 14:20	141																		
2018-05-12 14:40	142																		
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2018-05-13 5:40	187																		
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2018-05-13 6:40	190																		
2018-05-13 7:00	191																		
2018-05-13 7:20	192																		
2018-05-13 7:40	193	1.377	36.28	150.6	28.47	1.571	1.566	34.09	154.8	154.061	27.49	1.607	37.44	151.8	28.87	1.499	38.95	150.1	29.68
2018-05-13 8:00	194	1.857	31.02	153.3	23.66	2.071	2.064	29.48	153.8	153.065	22.62	2.107	28.72	151.3	22.85	1.988	31.55	150.8	23.7
2018-05-13 8:20	195	1.692	30.06	144.8	24.32	1.863	1.857	31.25	145.1	144.407	25.09	1.932	32.09	142.8	25.49	1.807	35.88	142.6	25.76
2018-05-13 8:40	196	1.629	42.96	136.7	37.15	1.74	1.734	46.07	138	137.341	37.64	1.795	45.69	134.3	38.78	1.723	43.75	134.4	37.25
2018-05-13 9:00	197	1.854	40.58	139.7	32.27	2.082	2.075	39.53	137.6	136.943	33.17	2.087	41.3	137	33.62	1.987	42.56	137.2	33.09
2018-05-13 9:20	198	1.242	51.74	133.5	39.54	1.444	1.439	52.18	138.9	138.236	39.95	1.454	54.71	135.9	41.22	1.367	56.6	132	42.47
2018-05-13 9:40	199	1.81	31.45	142.6	25.43	2.032	2.026	30.02	143.5	142.814	24.86	2.05	30.79	141.8	25.93	1.94	35.13	139.8	26.91
2018-05-13 10:00	200	1.803	32.75	141.9	26.12	2.029	2.023	28.46	144.8	144.108	24.72	2.038	31.01	142.6	25.4	1.923	34.65	141	25.94
2018-05-13 10:20	201	2.197	24.89	151.5	23.55	2.392	2.384	25.12	154.3	153.563	23.91	2.432	24.79	151.7	23.37	2.318	27.09	150	24.44
2018-05-13 10:40	202	1.798	30.63	148.2	24.52	2.011	2.005	29.19	148.9	148.189	24.34	2.061	30.17	147.9	24.82	1.928	33.62	146.3	24.77
2018-05-13 11:00	203	2.022	41.8	137.9	37	2.169	2.162	41.15	140	139.331	36.17	2.226	42.9	138.7	37.66	2.114	44.63	136.8	37.43
2018-05-13 11:20	204	1.548	37.24	148.6	32.24	1.747	1.741	37.9	149.3	148.587	32.16	1.776	40.1	147.6	32.64	1.651	44.35	145.8	33.69
2018-05-13 11:40	205	1.641	39.15	135.9	32.64	1.812	1.806	42.24	134.4	133.758	34.54	1.821	43.62	132.4	35.09	1.738	44.47	132.9	34.8
2018-05-13 12:00	206	1.603	39.09	155.2	32.17	1.781	1.775	38.01	156.8	156.051	31.02	1.796	39.14	153	32.29	1.694	42.34	153.3	32.83
2018-05-13 12:20	207	1.627	39.79	157	31.97	1.845	1.839	41.8	159.6	158.838	32	1.819	43.36	156.2	33.05	1.736	45.28	155.9	33.89
2018-05-13 12:40	208	1.398	48.7	114.5	42.74	1.513	1.508	51.45	121	120.422	44.17	1.552	52.56	113.1	45.49	1.496	51.73	113.9	43.71
2018-05-13 13:00	209	1.466	38.8	118.7	35.04	1.671	1.666	39.24	121	120.422	35.76	1.665	40.34	118.2	36.08	1.584	42.83	116.3	36.2
2018-05-13 13:20	210	1.617	46.99	127.2	41.2	1.759	1.753	46.45	128.9	128.284	40.7	1.769	46.4	125.3	41.08	1.722	48.21	124.9	41.79
2018-05-13 13:40	211	1.312	46.8	124.3	42.92	1.532	1.527	46.19	122.7	122.114	42.48	1.512	46.78	120.2	42.71	1.432	48.31	121.2	43.28
2018-05-13 14:00	212	1.562	33.15	153	28.49	1.778	1.772	30.72	154.7	153.961	27.47	1.786	33.45	151	29.25	1.694	36.02	151.8	28.99
2018-05-13 14:20	213	1.133	58.15	154	38.35	1.278	1.274	59.54	150.9	150.179	40.39	1.296	60.9	150.4	42.29	1.24	60.88	152.2	41.62
2018-05-13 14:40	214																		
2018-05-13 15:00	215																		
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2018-05-13 19:00	227																		
2018-05-13 19:20	228																		
2018-05-13 19:40	229																		

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**														
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc
2018-05-13 20:00	230																		
2018-05-13 20:20	231																		
2018-05-13 20:40	232																		
2018-05-13 21:00	233																		
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2018-05-13 22:00	236																		
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2018-05-13 23:40	241																		
2018-05-14 0:00	242																		
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2018-05-14 1:20	246																		
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2018-05-14 9:20	270																		
2018-05-14 9:40	271																		
2018-05-14 10:00	272																		
2018-05-14 10:20	273	1.104	48.37	162.8	35.59	1.322	1.318	44.94	168.3	167.496	35.67	1.326	46.32	162.6	36.36	1.221	49.45	161.6	36.69
2018-05-14 10:40	274	1.68	25.4	144.5	24.43	1.875	1.869	26.15	144.2	143.511	25.52	1.884	24.73	141.3	24.12	1.794	28.14	141.3	25.48
2018-05-14 11:00	275	1.706	26.54	170.2	20.75	1.842	1.836	29.9	173.3	172.472	21.65	1.848	28.41	168.6	22.46	1.744	30.94	168.8	22.61
2018-05-14 11:20	276	1.158	39.76	154.6	32.01	1.436	1.431	39.63	155.8	155.056	33.95	1.422	39.22	152	32.61	1.251	46.62	152.9	34.6
2018-05-14 11:40	277																		
2018-05-14 12:00	278																		
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2018-05-15 1:00	317																		
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2018-05-15 10:20	345																		
2018-05-15 10:40	346																		
2018-05-15 11:00	347																		
2018-05-15 11:20	348	1.12	35.02	191.7	31.38	1.293	1.289	37.52	197.9	196.955	33.14	1.339	35.9	189.7	31.73	1.244	40.57	192.8	33.88
2018-05-15 11:40	349																		
2018-05-15 12:00	350																		
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2018-05-15 15:40	361																		
2018-05-15 16:00	362																		
2018-05-15 16:20	363																		

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	VALIDATION - Remove data between 355-5; 174-186; <1.0m/s														
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc
2018-05-15 16:40	364																		
2018-05-15 17:00	365																		
2018-05-15 17:20	366																		
2018-05-15 17:40	367																		
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2018-05-16 8:20	411																		
2018-05-16 8:40	412	1.341	26.65	156.2	23.19	1.484	1.479	27.54	160.5	159.733	23.91	1.511	28.69	153	24.39	1.439	31.45	154.3	25.1
2018-05-16 9:00	413	1.305	31.39	160.6	24.74	1.47	1.465	32.11	163.8	163.018	25.69	1.484	32.79	157.2	25.78	1.419	35.7	158.5	26.3
2018-05-16 9:20	414	1.047	55.77	168.1	41.9	1.218	1.214	57.75	172.8	171.975	44.05	1.197	58.35	166.1	44.51	1.141	59.68	167	43.65
2018-05-16 9:40	415																		
2018-05-16 10:00	416	1.243	41.1	165.6	30.75	1.353	1.349	41.11	173.4	172.572	32.01	1.433	41.24	167	32.54	1.342	44.31	165.3	32.59
2018-05-16 10:20	417																		
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2018-05-17 7:20	480																		
2018-05-17 7:40	481																		
2018-05-17 8:00	482	1.021	35.32	156	26.98	1.222	1.218	40.36	157.3	156.549	30.73	1.255	42.18	151.9	31.84	1.12	42.96	153.8	29.98
2018-05-17 8:20	483	1.037	35.9	161.2	27.6	1.228	1.224	36.13	163	162.221	29.24	1.284	37.07	157.3	30.39	1.136	39.83	158.5	29.36
2018-05-17 8:40	484	1.144	35.24	162.4	26.58	1.27	1.266	37.4	168	167.197	27.96	1.316	38.38	159.3	29.6	1.229	40.02	161.5	28.77
2018-05-17 9:00	485																		
2018-05-17 9:20	486																		
2018-05-17 9:40	487	1.751	37.37	154.8	28.61	1.909	1.903	36.73	159	158.240	29.65	1.933	37.83	153.1	29.43	1.851	38.79	153.7	29.34
2018-05-17 10:00	488	1.611	28.23	160.5	23.65	1.782	1.776	29.28	165.2	164.411	24.65	1.802	29.12	159.7	24.56	1.732	32.17	159.1	25.39
2018-05-17 10:20	489																		
2018-05-17 10:40	490	1.329	40.82	166.6	30.14	1.527	1.522	41.16	171.9	171.079	32.27	1.527	42.68	165.3	32.09	1.457	44.04	165.6	32.82
2018-05-17 11:00	491	1.491	39.15	167.1	30.17	1.649	1.644	40.51	172.5	171.676	32.08	1.693	40.28	167.1	31.73	1.605	42.66	166.6	32.45
2018-05-17 11:20	492	1.569	23.75	159.1	19.83	1.748	1.742	22.92	161.6	160.828	19.72	1.818	22.29	157	19.62	1.687	28.32	157	21.57
2018-05-17 11:40	493	1.914	22.54	160	19.2	2.095	2.088	22.49	163.2	162.420	19.48	2.107	22.1	159.2	18.79	2.005	24.32	158.5	20
2018-05-17 12:00	494	1.529	32.55	154.1	27.84	1.732	1.726	35.97	156.5	155.752	30.01	1.743	36.11	152.9	30.21	1.625	39.05	152.4	30.46
2018-05-17 12:20	495																		
2018-05-17 12:40	496	1.059	53.96	186.6	41.44	1.2	1.196	51.94	195.2	194.268	41.24	1.28	52.94	187.8	43.03	1.148	57.02	187.3	43.85
2018-05-17 13:00	497																		

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**															
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004	
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg	
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	
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2018-05-18 12:00	566																			
2018-05-18 12:20	567	1.006	72.93	164.2	50.06	1.183	1.179	74.77	170.1	169.287	53.46	1.203	76.34	162.6	53.72	1.109	76.51	163	53.56	
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2018-05-19 8:00	626																			
2018-05-19 8:20	627																			
2018-05-19 8:40	628	1.015	22.57	149.4	19.88	1.134	1.130	29.69	150.6	149.881	23.67	1.145	29.75	144.4	23.51	1.096	31.75	147.2	22.88	
2018-05-19 9:00	629	1.071	48.99	163.2	30.27	1.249	1.245	54.89	165.1	164.311	34.91	1.234	53.27	162.2	33.91	1.143	53.75	161.6	33.22	
2018-05-19 9:20	630	1.306	56.27	161.2	42.9	1.458	1.453	58.09	162.5	161.724	44.21	1.47	60.46	159.6	44.84	1.396	60.71	159.3	44.95	
2018-05-19 9:40	631	2.236	22.8	164.9	20.57	2.437	2.429	22.12	167.1	166.302	20.62	2.432	22.54	162.8	21.09	2.344	24.62	163.1	21.79	

TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**														
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc
2018-05-19 10:00	632	1.921	32.43	157.5	28.31	2.081	2.074	32.36	159.8	159.037	28.79	2.08	32.47	156	28.62	1.983	33.93	156.4	28.66
2018-05-19 10:20	633	1.319	38.43	128.6	34.09	1.549	1.544	38.63	131	130.374	33.94	1.564	39.46	127.6	34.28	1.445	42.21	127.6	34.99
2018-05-19 10:40	634	1.357	28.75	129.8	25.73	1.576	1.571	28.69	131.4	130.772	25.63	1.594	29.56	128	25.98	1.487	33.05	128.1	26.32
2018-05-19 11:00	635	2.155	30.77	153.4	28.35	2.444	2.436	29.37	154.5	153.762	28.14	2.399	29.85	151.2	27.9	2.284	33.71	150.9	29.24
2018-05-19 11:20	636	1.636	37.41	145.7	30.69	1.818	1.812	37.09	148.3	147.592	30.82	1.86	38.27	143.6	31.82	1.726	40.79	143.7	31.48
2018-05-19 11:40	637	1.254	76.49	46.23	65.77	1.421	1.416	79.38	48.73	48.497	67.58	1.497	78.91	47.99	67.6	1.381	78.28	47.42	66.34
2018-05-19 12:00	638																		
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2018-05-19 12:40	640																		
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2018-05-19 13:20	642																		
2018-05-19 13:40	643	1.159	41.14	189.4	35.82	1.353	1.349	43.26	198.1	197.154	38.1	1.405	44.95	190.8	38.74	1.278	46.84	190.9	39.31
2018-05-19 14:00	644																		
2018-05-19 14:20	645																		
2018-05-19 14:40	646																		
2018-05-19 15:00	647	1.065	38.29	167.7	28.97	1.163	1.159	46.87	173.3	172.472	33.01	1.283	44.21	166.8	32.83	1.17	46.22	166.9	32.54
2018-05-19 15:20	648																		
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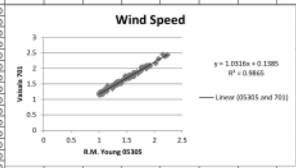
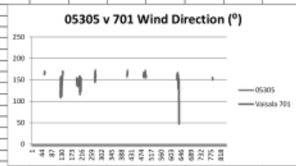
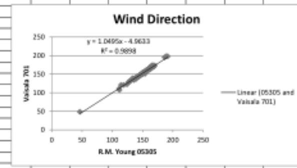
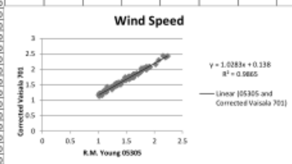
2018-05-21 6:20	765																		

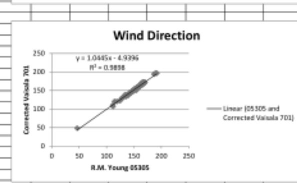
TOA5	CR3000 - Lab	CR3000	CR3000.Std.30.01	Table20	**VALIDATION - Remove data between 355-5; 174-186; <1.0m/s**														
TIMESTAMP	RECORD	WSPD_SCLR	SIGMA_20MIN	WDIR_VECT	SIGMA_20MIN_VECT	WSPD_SCLR_701	WSPD_SCLR_701	SIGMA_20MIN_701	WDIR_VECT_701	WDIR_VECT_701	SIGMA_20MIN_VECT_701	WSPD_SCLR_Gill	SIGMA_20MIN_Gill	WDIR_VECT_Gill	SIGMA_20MIN_VECT_Gill	WSPD_SCLR_86004	SIGMA_20MIN_86004	WDIR_VECT_86004	SIGMA_20MIN_VECT_86004
TS	RN		Deg	Deg	Deg		corrected	Deg	Deg	corrected	Deg		Deg	Deg	Deg		Deg	Deg	Deg
		WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc	WVc
2018-05-21 6:40	766																		
2018-05-21 7:00	767																		
2018-05-21 7:20	768																		
2018-05-21 7:40	769																		
2018-05-21 8:00	770																		
2018-05-21 8:20	771																		
2018-05-21 8:40	772																		
2018-05-21 9:00	773																		
2018-05-21 9:20	774																		
2018-05-21 9:40	775																		
2018-05-21 10:00	776																		
2018-05-21 10:20	777																		
2018-05-21 10:40	778																		
2018-05-21 11:00	779	1.232	51.75	154.6	39.93	1.403	1.399	53.83	156.4	155.653	42.13	1.406	54.46	152.2	42.57	1.321	53.24	152.7	41.24
2018-05-21 11:20	780																		
2018-05-21 11:40	781	1.244	50.55	149.3	39.16	1.426	1.421	54.23	152.7	151.971	42.5	1.485	54.14	147.3	42.7	1.352	53.91	147	41.29
2018-05-21 12:00	782	1.427	34.17	154.5	26.06	1.609	1.604	38.78	156.2	155.454	28.25	1.645	37.29	152	27.9	1.533	38.03	151.7	28.12
2018-05-21 12:20	783																		
2018-05-21 12:40	784																		
2018-05-21 13:00	785																		
2018-05-21 13:20	786																		
2018-05-21 13:40	787																		
2018-05-21 14:00	788																		
2018-05-21 14:20	789																		
2018-05-21 14:40	790																		
2018-05-21 15:00	791																		
2018-05-21 15:20	792																		
2018-05-21 15:40	793																		
2018-05-21 16:00	794																		
2018-05-21 16:20	795																		
2018-05-21 16:40	796																		
2018-05-21 17:00	797																		
2018-05-21 17:20	798																		
2018-05-21 17:40	799																		
2018-05-21 18:00	800																		
2018-05-21 18:20	801																		
2018-05-21 18:40	802																		
2018-05-21 19:00	803																		
2018-05-21 19:20	804																		
2018-05-21 19:40	805																		
2018-05-21 20:00	806																		
2018-05-21 20:20	807																		
2018-05-21 20:40	808																		
2018-05-21 21:00	809																		
2018-05-21 21:20	810																		
2018-05-21 21:40	811																		
2018-05-21 22:00	812																		
2018-05-21 22:20	813																		
2018-05-21 22:40	814																		
2018-05-21 23:00	815																		
2018-05-21 23:20	816																		
2018-05-21 23:40	817																		
2018-05-22 0:00	818																		
2018-05-22 0:20	819																		
2018-05-22 0:40	820																		
2018-05-22 1:00	821																		
2018-05-22 1:20	822																		
2018-05-22 1:40	823																		
2018-05-22 2:00	824																		
2018-05-22 2:20	825																		
2018-05-22 2:40	826																		
2018-05-22 3:00	827																		
2018-05-22 3:20	828																		
2018-05-22 3:40	829																		
2018-05-22 4:00	830																		
2018-05-22 4:20	831																		
2018-05-22 4:40	832																		
2018-05-22 5:00	833																		
2018-05-22 5:20	834																		
2018-05-22 5:40	835																		
2018-05-22 6:00	836																		
2018-05-22 6:20	837																		
2018-05-22 6:40	838																		
2018-05-22 7:00	839																		
2018-05-22 7:20	840																		
2018-05-22 7:40	841																		
2018-05-22 8:00	842	1.027	33.19	157.8	27.78	1.221	1.217	33.31	158.7	157.942	29.35	1.225	33.95	155.4	29.22	1.13	38.02	156	29.11

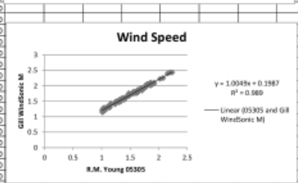


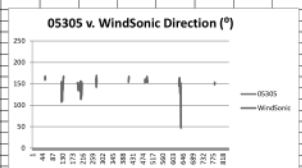


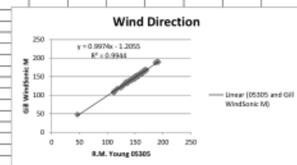


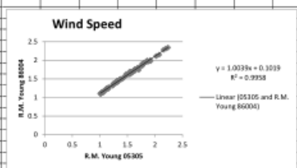


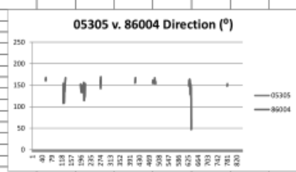


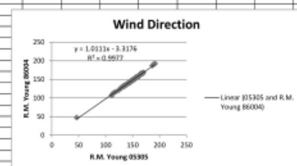












TOA5								
TIMESTAMP								
TS	Speed				Speed			
	701	701 corrected	Gill	86004	701	701 corrected	Gill	86004
2018-05-10 15:20								
2018-05-10 15:40								
2018-05-10 16:00								
2018-05-10 16:20								
2018-05-10 16:40								
2018-05-10 17:00								
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2018-05-11 7:40								
2018-05-11 8:00								
2018-05-11 8:20								
2018-05-11 8:40								
2018-05-11 9:00								
2018-05-11 9:20	0.193	-0.187	0.185	0.087	3.5	-2.714	-2.8	-1.4
2018-05-11 9:40	0.231	-0.224	0.177	0.077	1.8	-0.986	-2.4	-1.9
2018-05-11 10:00	0.195	-0.188	0.158	0.085	1.9	-1.111	-3.4	-2.1
2018-05-11 10:20								
2018-05-11 10:40								
2018-05-11 11:00								
2018-05-11 11:20								
2018-05-11 11:40								
2018-05-11 12:00								
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2018-05-11 22:00								
2018-05-11 22:20								
2018-05-11 22:40								
2018-05-11 23:00								

TOA5								
TIMESTAMP								
TS	Speed				Speed			
	701	701 corrected	Gill	86004	701	701 corrected	Gill	86004
2018-05-11 23:20								
2018-05-11 23:40								
2018-05-12 0:00								
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2018-05-12 0:40								
2018-05-12 1:00								
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2018-05-12 7:00								
2018-05-12 7:20								
2018-05-12 7:40								
2018-05-12 8:00								
2018-05-12 8:20								
2018-05-12 8:40	0.193	-0.188	0.202	0.139	-4.4	4.913	-4.9	-4.3
2018-05-12 9:00	0.208	-0.202	0.192	0.119	2.7	-1.946	-0.8	-1.8
2018-05-12 9:20	0.235	-0.229	0.237	0.156	2.1	-1.452	-0.6	-1.2
2018-05-12 9:40	0.269	-0.263	0.243	0.139	1.1	-0.395	-2.2	-2.1
2018-05-12 10:00	0.216	-0.211	0.225	0.114	-0.3	0.830	-2.5	-3.5
2018-05-12 10:20	0.273	-0.267	0.285	0.156	2.3	-1.587	-0.8	-2.4
2018-05-12 10:40	0.139	-0.133	0.158	0.112	2.9	-2.242	-1.3	-1
2018-05-12 11:00	0.206	-0.199	0.22	0.125	2.2	-1.490	-1.2	-1.5
2018-05-12 11:20	0.216	-0.210	0.237	0.121	2	-1.249	-2.2	-2.2
2018-05-12 11:40	0.184	-0.179	0.194	0.101	1.4	-0.609	-2.5	-2.1
2018-05-12 12:00	0.148	-0.142	0.176	0.085	3	-2.183	-0.7	-1
2018-05-12 12:20								
2018-05-12 12:40								
2018-05-12 13:00								
2018-05-12 13:20	0.134	-0.129	0.218	0.08	2	-1.200	-0.9	-1.7
2018-05-12 13:40								
2018-05-12 14:00								
2018-05-12 14:20								
2018-05-12 14:40								
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2018-05-13 6:20								
2018-05-13 6:40								
2018-05-13 7:00								
2018-05-13 7:20								
2018-05-13 7:40	0.194	-0.189	0.23	0.122	4.2	-3.461	1.2	-0.5
2018-05-13 8:00	0.214	-0.207	0.25	0.131	0.5	0.235	-2	-2.5
2018-05-13 8:20	0.171	-0.165	0.24	0.115	0.3	0.393	-2	-2.2
2018-05-13 8:40	0.111	-0.105	0.166	0.094	1.3	-0.641	-2.4	-2.3
2018-05-13 9:00	0.228	-0.221	0.233	0.133	-2.1	2.757	-2.7	-2.5
2018-05-13 9:20	0.202	-0.197	0.212	0.125	5.4	-4.736	2.4	-1.5
2018-05-13 9:40	0.222	-0.216	0.24	0.13	0.9	-0.214	-0.8	-2.8
2018-05-13 10:00	0.226	-0.220	0.235	0.12	2.9	-2.208	0.7	-0.9
2018-05-13 10:20	0.195	-0.187	0.235	0.121	2.8	-2.063	0.2	-1.5
2018-05-13 10:40	0.213	-0.207	0.263	0.13	0.7	0.011	-0.3	-1.9
2018-05-13 11:00	0.147	-0.140	0.204	0.092	2.1	-1.431	0.8	-1.1
2018-05-13 11:20	0.199	-0.193	0.228	0.103	0.7	0.013	-1	-2.8
2018-05-13 11:40	0.171	-0.165	0.18	0.097	-1.5	2.142	-3.5	-3
2018-05-13 12:00	0.178	-0.172	0.193	0.091	1.6	-0.851	-2.2	-1.9
2018-05-13 12:20	0.218	-0.212	0.192	0.109	2.6	-1.838	-0.8	-1.1
2018-05-13 12:40	0.115	-0.110	0.154	0.098	6.5	-5.922	-1.4	-0.6
2018-05-13 13:00	0.205	-0.200	0.199	0.118	2.3	-1.722	-0.5	-2.4
2018-05-13 13:20	0.142	-0.136	0.152	0.105	1.7	-1.084	-1.9	-2.3
2018-05-13 13:40	0.22	-0.215	0.2	0.12	-1.6	2.186	-4.1	-3.1
2018-05-13 14:00	0.216	-0.210	0.224	0.132	1.7	-0.961	-2	-1.2
2018-05-13 14:20	0.145	-0.141	0.163	0.107	-3.1	3.821	-3.6	-1.8
2018-05-13 14:40								
2018-05-13 15:00								
2018-05-13 15:20								
2018-05-13 15:40								
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TOA5								
TIMESTAMP								
TS	Speed				Speed			
	701	701 corrected	Gill	86004	701	701 corrected	Gill	86004
2018-05-13 20:00								
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2018-05-14 9:00								
2018-05-14 9:20								
2018-05-14 9:40								
2018-05-14 10:00								
2018-05-14 10:20	0.218	-0.214	0.222	0.117	5.5	-4.696	-0.2	-1.2
2018-05-14 10:40	0.195	-0.189	0.204	0.114	-0.3	0.989	-3.2	-3.2
2018-05-14 11:00	0.136	-0.130	0.142	0.038	3.1	-2.272	-1.6	-1.4
2018-05-14 11:20	0.278	-0.273	0.264	0.093	1.2	-0.456	-2.6	-1.7
2018-05-14 11:40								
2018-05-14 12:00								
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2018-05-15 11:20	0.173	-0.169	0.219	0.124	6.2	-5.255	-2	1.1
2018-05-15 11:40								
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2018-05-16 8:40	0.143	-0.138	0.17	0.098	4.3	-3.533	-3.2	-1.9
2018-05-16 9:00	0.165	-0.160	0.179	0.114	3.2	-2.418	-3.4	-2.1
2018-05-16 9:20	0.171	-0.167	0.15	0.094	4.7	-3.875	-2	-1.1
2018-05-16 9:40								
2018-05-16 10:00	0.11	-0.106	0.19	0.099	7.8	-6.972	1.4	-0.3
2018-05-16 10:20								
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2018-05-17 8:00	0.201	-0.197	0.234	0.099	1.3	-0.549	-4.1	-2.2
2018-05-17 8:20	0.191	-0.187	0.247	0.099	1.8	-1.021	-3.9	-2.7
2018-05-17 8:40	0.126	-0.122	0.172	0.085	5.6	-4.797	-3.1	-0.9
2018-05-17 9:00								
2018-05-17 9:20								
2018-05-17 9:40	0.158	-0.152	0.182	0.1	4.2	-3.440	-1.7	-1.1
2018-05-17 10:00	0.171	-0.165	0.191	0.121	4.7	-3.911	-0.8	-1.4
2018-05-17 10:20								
2018-05-17 10:40	0.198	-0.193	0.198	0.128	5.3	-4.479	-1.3	-1
2018-05-17 11:00	0.158	-0.153	0.202	0.114	5.4	-4.576	0	-0.5
2018-05-17 11:20	0.179	-0.173	0.249	0.118	2.5	-1.728	-2.1	-2.1
2018-05-17 11:40	0.181	-0.174	0.193	0.091	3.2	-2.420	-0.8	-1.5
2018-05-17 12:00	0.203	-0.197	0.214	0.096	2.4	-1.652	-1.2	-1.7
2018-05-17 12:20								
2018-05-17 12:40	0.141	-0.137	0.221	0.089	8.6	-7.668	1.2	-0.7
2018-05-17 13:00								

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2018-05-18 12:20	0.177	-0.173	0.197	0.103	5.9	-5.087	-1.6	-1.2
2018-05-18 12:40								
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2018-05-19 8:20								
2018-05-19 8:40	0.119	-0.115	0.13	0.081	1.2	-0.481	-5	-2.2
2018-05-19 9:00	0.178	-0.174	0.163	0.072	1.9	-1.111	-1	-1.6
2018-05-19 9:20	0.152	-0.147	0.164	0.09	1.3	-0.524	-1.6	-1.9
2018-05-19 9:40	0.201	-0.193	[illegible]	[illegible]	[illegible]	-1.402	[illegible]	[illegible]

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	701	701 corrected	Gill	86004	701	701 corrected	Gill	86004
2018-05-19 10:00	0.16	-0.153	0.159	0.062	2.3	-1.537	-1.5	-1.1
2018-05-19 10:20	0.23	-0.225	0.245	0.126	2.4	-1.774	-1	-1
2018-05-19 10:40	0.219	-0.214	0.237	0.13	1.6	-0.972	-1.8	-1.7
2018-05-19 11:00	0.289	-0.281	0.244	0.129	1.1	-0.362	-2.2	-2.5
2018-05-19 11:20	0.182	-0.176	0.224	0.09	2.6	-1.892	-2.1	-2
2018-05-19 11:40	0.167	-0.162	0.243	0.127	2.5	-2.267	1.76	1.19
2018-05-19 12:00								
2018-05-19 12:20								
2018-05-19 12:40								
2018-05-19 13:00								
2018-05-19 13:20								
2018-05-19 13:40	0.194	-0.190	0.246	0.119	8.7	-7.754	1.4	1.5
2018-05-19 14:00								
2018-05-19 14:20								
2018-05-19 14:40								
2018-05-19 15:00	0.098	-0.094	0.218	0.105	5.6	-4.772	-0.9	-0.8
2018-05-19 15:20								
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2018-05-21 11:00		0.171	-0.167	0.174	0.089	1.8	-1.053	-2.4	-1.9	
2018-05-21 11:20										
2018-05-21 11:40		0.182	-0.177	0.241	0.108	3.4	-2.671	-2	-2.3	
2018-05-21 12:00		0.182	-0.177	0.218	0.106	1.7	-0.954	-2.5	-2.8	
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2018-05-22 7:00										
2018-05-22 7:20										
2018-05-22 7:40										
2018-05-22 8:00		0.194	-0.190	0.198	0.103	0.9	-0.142	-2.4	-1.8	
	Average	0.18579	-0.180421	0.20603	0.10778	2.49178	-1.759945	-1.59781	-1.64671	
	Std dev	0.03919	0.038828	0.03323	0.02039	2.36758	2.317482	1.50146	0.99316	
		701		Gill	86004	701		Gill	86004	
		Speed				Direction				
									72	24

COST COMPARISON SUMMARY						
	Status Quo	**Option 1**	**Option 2**	**Option 3a**	**Option 3b**	**Option 3c**
TOTAL CAPITAL	**$ 52,550.00**	**$ 52,550.00**	**$ 142,210.17**	**$ 77,613.00**	**$ 77,613.00**	**$ 77,613.00**
FTE ($)	$ 44,452.78	$ 88,905.56	$ 19,454.29	$ 35,111.50	$ 21,055.95	$ 21,097.02
Operational ($)	$ 52,570.00	$ 106,110.00	$ 53,421.59	$ 52,834.04	$ 47,654.04	$ 70,448.04
TOTAL OPERATIONAL	**$ 97,022.78**	**$ 195,015.56**	**$ 72,875.89**	**$ 87,945.54**	**$ 68,709.99**	**$ 91,545.06**
TOTAL	**$ 149,572.78**	**$ 247,565.56**	**$ 215,086.05**	**$ 165,558.54**	**$ 146,322.99**	**$ 169,158.06**
Capital + Operational	**$ 105,120.00**	**$ 158,660.00**	**$ 195,631.76**	**$ 130,447.04**	**$ 125,267.04**	**$ 148,061.04**
Investment Efficiency*	**$ -**	**$ -**	**$ 148.69**	**$ 111.35**	**$ 35.43**	**$ 75.51**
Amort ($/yr over 5y)	$ 10,510.00	$ 10,510.00	$ 28,442.03	$ 15,522.60	$ 15,522.60	$ 15,522.60
FTE (h)	1082.4	2164.8	473.7	855.0	513.7	513.71

*Evaluates how much each reduced FTE hour costs based on differential in operating costs.

*Investment efficiency = ((option capital + operational cost)-(status quo capital + operational cost)/(option FTE h - status quo FTE h)

Score					
	Option 1	**Option 2**	**Option 3a**	**Option 3b**	**Option 3c**
Cost (Capital + Ops)	35.5	28.8	43.2	45.0	38.1
Time (h)	9.8	45.0	24.9	41.5	41.5

TMGT 8104

B.C. Air Quality Program – Meteorological Monitoring Network Project

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July 13th, 2018

Approved by

Signature **Date**

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Faculty Advisor
British Columbia Institute of Technology

Signature **Date**

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British Columbia Ministry of Environment and Climate Change Strategy

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Acronyms and Abbreviations

ASCII – American Standard Code for Information Interchange
AMD – Air Monitoring Directive

CA – Clean Air
CARB – California Air Resources Board
CTS – Collocated Transfer Standard
CO – Carbon Monoxide

DC – Direct Current
DQO – Data Quality Objective

ECMS – Environmental and Climate Monitoring
ENV – British Columbia Ministry of Environment

EU – Envidas Ultimate
MAS – Monitoring, Assessment and Stewardship
mA – milliamp
m/s – meters per second

NWS – National Weather Service
NPT – National Pipe Thread
NOx – Oxides of Nitrogen
O_3 – Ozone

PAMS – Photochemical Assessment Monitoring Station
PM – Particulate Matter

RH – Relative Humidity

SO_2 - Sulphur Dioxide

UCL – Urban Canopy Layer
UCZ – Urban Climate Zone
USEPA – United States Environmental Protection Agency

VDC – Volts Direct Current

WMO- World Meteorological Organization

Executive Summary

The following report provides an evaluation of meteorological instrumentation performance within the B.C. Ministry of Environment and Climate Change Strategy's air quality network. Performance of current wind sensors falls below accepted thresholds, negatively impacting data quality.

Data users indicate that standards should not be relaxed, and a review of other jurisdictions demonstrates that the Ministry's objectives are realistic and achievable, so a new approach to data collection is required; however, this does not mean that change is required at all sites: roof-top monitoring locations can be problematic as the instruments can be overly influenced by microscale influences (the building itself). A more thorough review should take place within the context of a routine network review.

Ultrasonic wind sensors were tested and performed well - within or near the acceptance criteria of the test. Other mechanical sensors were reviewed, but this option was not pursued as it didn't seem to offer a data quality or cost advantage. A business case analysis was conducted to compare multiple options. This indicated that a reduced maintenance interval at roof-top locations, coupled with increased investment at ground-based towers will lead to improved data quality at well-sited stations.

This would see new instrumentation deployed at 12 stations, requiring a capital investment of $77,613 over two years. This falls within the available funding envelope for this fiscal year, compared to a status-quo investment of $52,550, which will not address data quality. The increase in capital is more than offset within the five-year amortization of the instrumentation, as there is a corresponding reduction in operational costs from $52,572 to $47,654. More importantly there is a drop in required staff time by almost 47%, equivalent to over $23,000 in staffing costs. This sees a break-even point just over 58 months into instrument deployment when compared to status quo.

A costed plan to procure equipment, train staff, and deploy the equipment is contained within this report, and would see the project wrap up in the summer of 2020. Coupled with this are recommendations to improve reporting by data and systems staff to more fully inform data users of data quality, leading to better data use, and ultimately better environmental outcomes.

1. Background

The B.C. Ministry of Environment and Climate Change Strategy (ENV or "the Ministry") operates a large, geographically distributed network of air quality monitoring stations. These stations house instrumentation monitoring for common pollutants such as Oxides of Nitrogen (NO_x), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3) and Particulate Matter (PM) ≤10 µm or ≤2.5 µm in diameter (PM_{10} and $PM_{2.5}$). They are generally located in populated areas to enable human-health related assessments of the environment, though some are located close to large industrial facilities, or in sparsely populated areas to investigate or identify and characterise environmental impacts from specific activities. Co-located with many monitoring stations are meteorological towers to aid air quality meteorologists and other data users interpret and make use of the pollutant data collected.

This project aims to address two technology questions to inform decision making with respect to instrument deployment:

- Can, and should, sensor technology be changed to improve data quality, and reduce operating costs and human resource requirements?
- Can this lead to a reduction in datalogging equipment requirements (Wiederick, 2017)?

This was refined to deliver six key deliverables:

- A needs analysis of equipment
- An assessment of current equipment
- Research and technology assessment of new equipment options
- A business case for recommended solutions
- Defined success metrics
- An implementation plan for the recommended solution

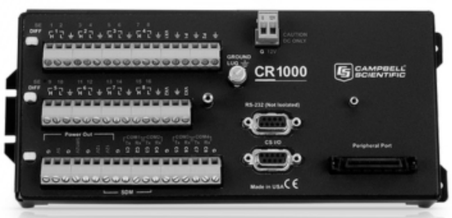
This project was initiated after some comments from one of our service providers – the wind sensors in use were in rough shape when returned from the field, so data quality was suffering. Some limited data analysis followed which confirmed that the instruments routinely did not meet performance criteria when evaluated, and ultrasonic instruments were purchased for testing. Staffing limitations did not permit immediate testing, so the project stalled – this project provides a structured approach to confirm and expand that analysis, identify solutions, and test the new instrumentation already purchased.

2. Technology Assessment

2.1. Typical Instrument Deployment

The current network includes 28 meteorological towers – these are typically 10 meters tall and outfitted with propeller-and-vane style anemometers and an integrated temperature and relative humidity (RH) probe. A few towers include additional instrumentation such as barometric pressure or snow depth sensors – these have not been integrated into this project as they are non-standard, and will not meaningfully inform the outcome. Wind parameters are almost exclusively monitored with the R.M. Young 05305 (left), and temperature and humidity is measured with either a now-discontinued Vaisala HMP45C or a Rotronic HC2-S3. There are a few cup-and-vane anemometers in use that directly connect to Met One PM monitors. These are typically used for short-term deployments at non-standard measurement heights. Meteorological measurements are generally transmitted as analog signals to Campbell Scientific dataloggers - either a discontinued 21x or 23x, or newer CR1000 (above) or CR3000.

CR1000 Datalogger



Retrieved June 26, 2017 from https://www.campbellsci.ca/cr1000

RM Young 05305

Retrieved June 24, 2017 from http://www.youngusa.com/products/7/6.html

CR1000 loggers and Rotronic probes have slowly been introduced as older instruments fail, or as incremental upgrades – there is no formal implementation plan or timeline for the phase out of older loggers and sensors; Table 1 (below) summarizes the current technology mix.

Table 1 - Number of Deployed Meteorological Instruments

Model and Number of Deployed Meteorological Instruments		
Dataloggers	**Temperature and RH**	**Wind**
CR3000 – 1	HMP45C – 21	R.M. Young 05305 - 27
CR1000 – 13	HC2-S3 – 7	-
23x – 5	-	-
21x – 9	-	-

2.2. Instrument Maintenance and Calibration

All sensors undergo periodic maintenance to ensure that the data collected meet a known, verifiable standard.

Temperature and RH probes are removed from the field every two years and assessed against reference standards at multiple humidity levels (25%, 50%, 75%), and a reference temperature of 23^{o}C or 24^{o}C. Probes will be calibrated should their response deviate outside of their prescribed performance standard. R.M. Young anemometers are serviced at six-month intervals over a two year cycle as per Table 2.

The 360^{o} check is conducted by orienting the sensor with known directions and recording the data output on the logger. This should be done with an alignment jig, but sometimes markings on the instrument housing are used as reference points.

The nose cone bearings are changed out annually – these are the bearings that the propeller shaft spins on, so increased resistance due to wear will impact wind speed measurements. Every two years the entire instrument is removed from the field for rebuild: the vertical shaft bearings on which the entire unit pivots, and the potentiometer used to indicate wind direction are replaced. In addition to the items above technicians inspect the temperature/humidity probe for cleanliness and replace the dust-cap annually, and have the datalogger serviced every five years (BC Ministry of Environment [BCENV], 2007).

Table 2 - BC ENV Standard Wind Sensor Maintenance Intervals

Wind Sensor Maintenance Intervals	
Interval	**Action**
6 months	verify alignment; conduct 360 º check
12 months	verify alignment; conduct 360 º check; replace nose cone bearings
18 months	conduct 360 º check
24 months	conduct 360 º check; remove from field for bench test; potentiometer replacement; vertical shaft bearing replacement

Table 3 - Performance Criteria for the R.M. Young 05305

Variable	Acceptance Standard (@ 0.5 m/s and 10º displacement)
Direction (Azimuth)	±3°
Vane Torque	≤11 gm/cm
Wind Speed	±0.3 m/s
Propeller Torque	≤1 gm/cm

(R.M. Young Company, a) (R.M. Young Company, b)
(Wiederick, 2017, p. 7)

The most in-depth evaluation is done when the sensor is removed from the field allowing for "as-found" checks to be conducted. These checks provide pass/fail performance criteria for the sensor, and allow for inferences about the data collected:

- The propeller shaft is driven at known revolutions per minute and the reported speed is verified in meters per second (m/s).
- The instrument is mounted on an alignment jig and stepped through various directions to test the operation of the potentiometer.
- Torque measurements are taken for both the nose-cone and vertical shaft bearings to establish the starting speed of the instrument. For direction this is defined as "the lowest speed at which a vane will turn to within 5° of the true wind direction from an initial displacement of 10° (United States Environmental Protection Agency [USEPA], 2000, p. 2-4).

On completion of the "as-found" checks the potentiometer and all bearings are replaced. "As-left" checks are then conducted to confirm performance, and the sensor is returned for future field deployment.

2.3. Current Instrument Assessment

2.3.1. Method

The performance of deployed meteorological instruments was characterized through an analysis of "as-found" data. This was an iterative process:

- Initially 3 years of instrument assessment data were reviewed to confirm the comments of our contractor, which also led to the selection and acquisition of new sensors to test.
- Through the development of this project's plan, this analysis was expanded to five years.
- It was then further refined by converting torque measurements to approximate wind speeds and expanded to include temperature and RH sensors.

Wind sensor performance was evaluated by reviewing and compiling information from all reports provided by Campbell Scientific Canada, and B.J. Bevan, who conducted all instrument overhauls between October 2013 and March 2017 (51 sensors - see Appendix A). The maximum error observed for all parameters in Table 3 were recorded, though the data from six sensors were discarded where the instruments were noted as damaged. Torque values were converted to wind speed based on the following formula (R.M. Young Company, a, pp. 9-10, 12, 14) (R.M. Young Company, b, p. 2):

$$U = \sqrt{(T/K)}$$

Where:

U = wind speed (m/s)

K = constant: 37 (wind direction); 3.8 (wind speed)

T = torque (gm-cm)

A similar approach was taken with temperature and relative humidity probes: 67 calibration files from 2013-2017 were reviewed and the deviations from expected values for all as-found checks were recorded. To benchmark RH sensor performance the worst performing sensor was selected and values were converted to an approximate dew point (accuracy max error ±0.083%) (Vaisala Oyj, 2013, pp. 3-7):

$$Td = \frac{Tn}{\left[\frac{m}{10_{\log}\left(\frac{Pw}{A}\right)}\right] - 1}$$

Where:

- Td = dew point
- RH = relative humidity
- Tn = 240.7263
- m = 7.591386
- A = 6.116441
- $RH = (P_w/P_{ws})100$
- $P_{ws} = A \times 10^{\frac{(m \times T)}{T+Tn}}$
- $T = 24.0$°C (probe temperature)

2.3.2. Results

While the sensors retain the ability to accurately report speed when spun at a known rate, azimuth routinely exceeded 3^{o} (see Figure 3), and the starting threshold for direction is almost always outside of the stated standard (see Figure 1). The as-found max torque error for each sensor has been converted to a starting wind speed in the frequency distributions in Figures 2 and 4, with green bars indicating sensors within specification. A 0.4 m/s starting threshold for wind speed, and 0.5 m/s starting threshold for wind direction is stated in ENV's *Meteorological Data and Sensing Requirement* (2013, p. 1). Similarly 0.5 m/s is the recommended threshold for wind sensors in the United States Environmental Protection Agency's (USEPA) *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (2000, p. 5-3). Further ENV states "that anemometers at most Ministry and [Metro Vancouver] sites have a starting threshold of 1 km/hr (approximately 0.5 m/s)" in the *British Columbia Air Quality Dispersion Modelling Guideline* (2015, p.39).

Generally, performance of temperature and humidity probes is better than the wind sensors with 13 of 67 falling outside of as found tolerance checks; however, these thresholds and data quality requirements are different:

Figure 1 - 05305 Failure Rate by Performance Check

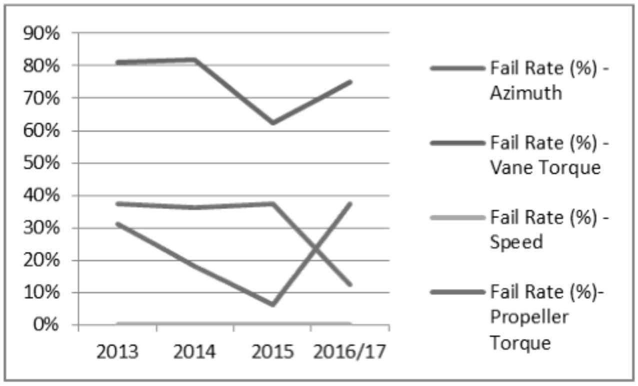


Figure 2 - Wind Direction Starting Thresholds

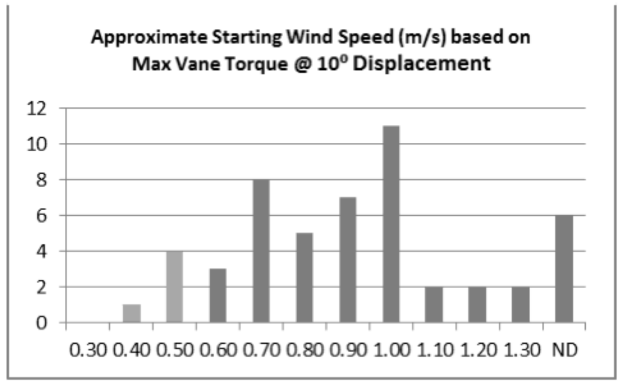


Figure 3 - Azimuth As-Found Max Error Distribution

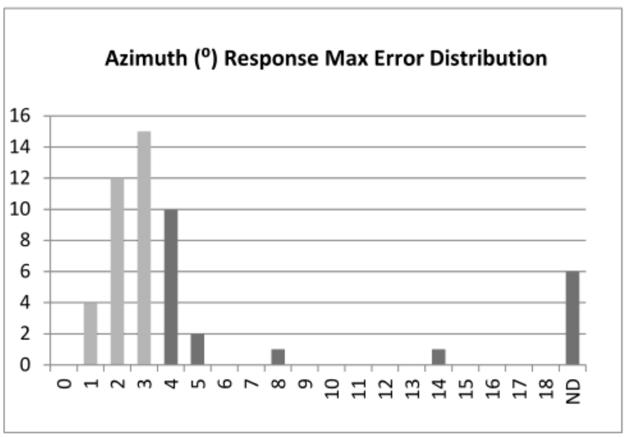
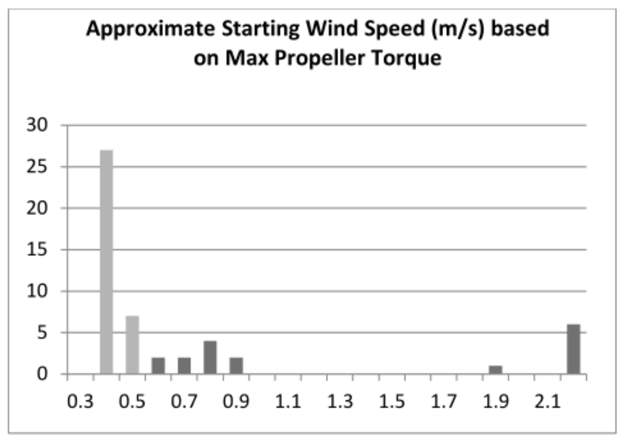


Figure 4 - Propeller Torque Max As-Found Error Distribution



The Ministry's sensing requirements call for accuracy of ±0.2⁰C for temperature, and ±1.0% @ 20⁰C against a factory reference for RH (B.C. Ministry of Environment [BCMOE], 2013). Note that the sensing requirements are not officially approved policy and are not incorporated into the British Columbia Field Sampling Manual.

This meets the accuracy of the sensors:

- HC2S3: ±0.1⁰C @ 23⁰C and ±0.8% RH @ 23⁰C (Campbell Scientific Inc., 2017, p. 6); and,
- HMP45C: ±0.2⁰C at 20⁰C and ±2.0% RH @ 20⁰C and within 0-90% RH, ±3.0% above 90% (Campbell Scientific (Canada)Corp., 2010, pp. 1-2).

USEPA guidance for modelling-quality data suggests system accuracy of ±0.5⁰C for temperature, and ±1.5⁰C of dew point (USEPA, 2000, p. 5-1). Clarification for applying this metric to RH is found within the

USEPA's *Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV: Meteorological Measurements Version 2.0 (Final)* (2008, section 5.4 p. 4)*:* for RH values below 40%, use ±7% RH, and above this threshold use ±1.5°C of dew point.

The sensor with the greatest deviation from expected values was out by -2.6% @ 25% RH; -4.6% @ 50% RH and -4.7% @ 75% (HMP45C S/N 8037, 24 Oct 2013), so dew point was calculated at corresponding humidity values: 45.4%, 50%, 70.3%, and 75% as outlined in Table 4.

Table 4 – Calculated Relative Humidity Sensor Error

Actual RH (%)	Dew Point (°C)	Measured RH (%)	Dew Point (°C)	Error (°C)
50	12.938	45.4	11.537	1.401
75	19.292	70.3	18.258	1.036

Based on these results this sensor is outside of the manufacturer's specification, but still meets USEPA guidance for system accuracy. It is recognised for both temperature and RH that errors present in-situ such as signal transmission, digital-analog conversion at the logger, or environmental heating due to dirty radiation shields has not been quantified so system accuracy has not been assessed. However, this was the worst performing RH sensor which had atypical as-found results (see Figure 6), and there were no temperature sensor errors >0.3°C (see figure 5).

Figure 5 - Max Temperature Sensor Error

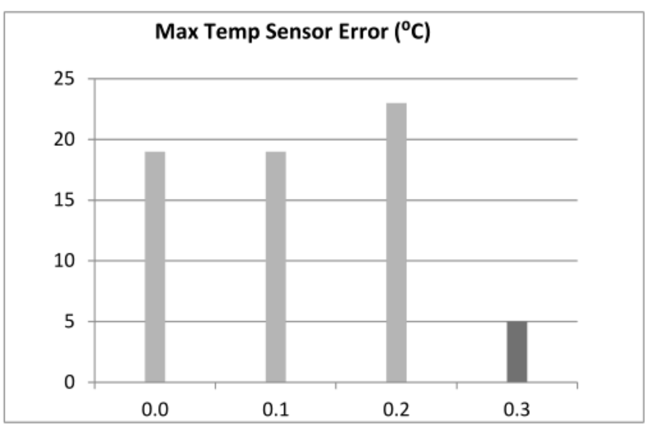
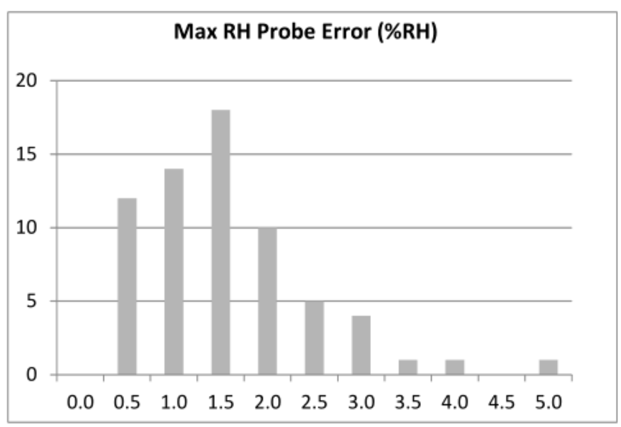


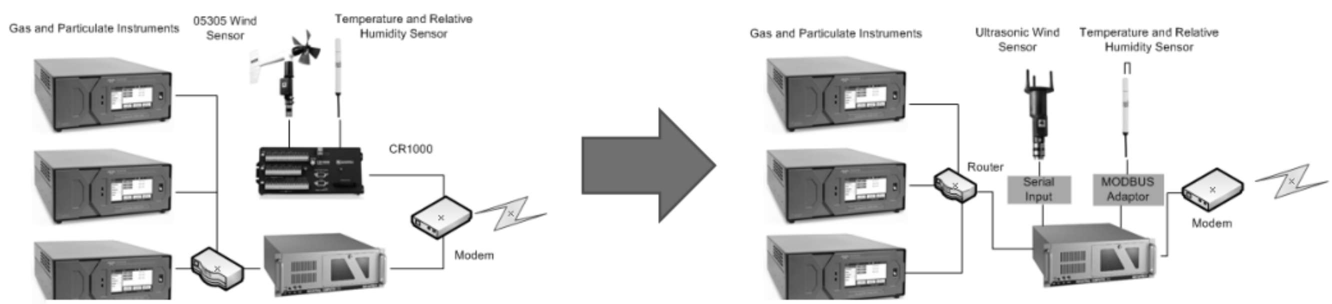
Figure 6 - Max Relative Humidity Probe Sensor Error



2.4. Discussion

Temperature and RH readings do not seem to be problematic, but wind measurements are. The selection of ultrasonic sensors as an alternative to mechanical instruments was primarily because they do not have moving parts, so there is no opportunity for wear on the sensor's components. This also led to the identification of an opportunity to potentially streamline network configuration: remove the Campbell Scientific datalogger from sites where a PC-based system already exists – Envidas Ultimate (EU) (Wiederick, 2017, p. 11). This would leverage the serial communications protocols available with ultrasonic sensors if they can be demonstrated to: provide comparable data to a well-functioning R.M. Young 05305; communicate with our existing ambient air data logging system; and, temperature and humidity probes are also compatible with EU as per Figure 7 below.

Figure 7 - Potential Change in System Configuration



Adapted from Adapted from *TMGT 8101 – Directed Studies – BC Air Quality Monitoring Program – Meteorological Monitoring Network Project Plan*. Wiederick. (2017, pp. 10-11)

3. Needs assessment

Any investment in technology needs to be based on a solid understanding of user needs and be referenced to accepted practices. To address this, three separate assessments were conducted: a cross-jurisdictional scan, user engagement, and a web-based site assessment to characterise whether monitoring stations are sufficiently spatially representative of local conditions.

3.1. Cross-Jurisdictional Scan

A scan of other jurisdictions was completed to ensure that B.C. is not implementing a monitoring program that could be interpreted as unwarranted given accepted practices. Metro Vancouver was contacted to determine whether they had developed any their own guidance, and available documentation was reviewed from two large U.S. states, as well as a neighboring province, and the Meteorological Service of Canada.

3.1.1. Metro Vancouver

Metro Vancouver requires that data being collected for dispersion modelling be of higher quality than if not used for this purpose. They indicated that both ENV's guidance and the USEPA's *Meteorological Monitoring Guidance for Regulatory Modeling Applications* had been referenced in the past, with the latter being used when making recommendations to consultants.

3.1.2. Alberta

Air Monitoring Standards are prescribed in Alberta Environment's *Air Monitoring Directive* (2017, p. 14) (AMD), specifically chapter four which outlines technical specifications. Alberta does not require a specific technology be adopted, rather it indicates acceptable detection methods such as prop and vane, ultrasonic etc., and minimum performance specifications (see Table 5).

Beyond performance specifications, the AMD requires that mechanical wind sensors be taken from the meteorological tower at least annually for mechanical inspection or factory calibration. Ultrasonic sensors must be "electronically inspected" (Government of Alberta, 2016, pp. 22-23) annually, which seems to be limited to ensuring that wind parameters are being measured by the instrument, and that heaters are functional. Every two years operators are required to have the instruments undergo factory calibration.

3.1.3. California

The California Air Resourced Board's (CARB) standards for meteorological monitoring data are stated within the *Annual Data Quality Report 2016* (2017). CARB states that the "level of acceptability" for meteorological data collected within their jurisdiction are "those used by [US] EPA for both the Prevention of Significant Deterioration and Photochemical Assessment Monitoring programs" (California Air Resources Board, 2017, pp 66-67). These thresholds are presented in Table 5.

For context: Prevention of Significant Deterioration monitoring is conducted to prevent newly permitted facilities from impacting areas that are either unclassifiable, or already meet the National Ambient Air Quality Standard; the Photochemical Assessment Monitoring (PAMS) network monitors for ground level O_3 and O_3 precursors at National Core stations in large communities (population >1,000,000), and in some areas that do not attain O_3 standards (USEPA, 2017, section 1.0, pp. 4-5).

3.1.4. Texas

Texas operates surface meteorological instrumentation where required by federal regulation, such as PAMS sites, and "most network sites" (Texas Commission on Environmental Quality [TCEQ], 2017, p. 25). Texas' network site list was reviewed and network-type recorded for each wind sensor – of 104 instruments, 79 were identified as Special Purpose Monitoring, with a further 25 identified as State or Local Air Monitoring Stations (TCEQ, 2017, pp. A1 – A42, J-1 – J-2). As such, accuracy requirements are available as published by the USEPA.

3.1.5. Meteorological Service of Canada

The Meteorological Service of Canada's (MSC) *Automatic Weather Station Configuration Manual* (2016) does not provide a performance standard for wind monitors; rather, it provides detailed instructions on the set-up and configuration of a standardized set of equipment. In this network the R.M Young 05103 is the standard instrument for the collection of surface wind data (Environment and Climate Change Canada, 2016, p. 114). Table 5 provides selected performance specifications, as per the 05103 operating manual.

Table 5- Select Wind Sensor Requirements

	B.C.	Alberta	MSC	California (PAMS/PSD)	Texas (SLAMS/SPM)
Wind Speed Range	0.0-50.0 m/s	0.0-50.0 m/s	0-100 m/s	0.5-50.0 m/s	0.5-50.0 m/s
Wind Speed Accuracy	±0.2 m/s	±0.25 m/s or 2% of reading	±0.3 m/s	±0.2 m/s +5%	±0.25m/s ≤5m/s; 5%>2m/s not to exceed 2.5m/s
Wind Direction Range	0-360°; 5° dead-band permitted	0-360°`	0-360; 5° dead-band	0 – 360° (540°)	0 – 360° (540°)
Wind Direction Accuracy	±3°	±3°		±5° (PAMS);includes orientation error (PSD)	±5°; includes orientation error
Starting Threshold	0.4 m/s speed; 0.5 m/s direction	0.5 m/s	1.0 m/s speed; 1.1 m/s direction	-	-
Distance Constant	≤2.1 m	<3 m	2.7 m	-	-

(Government of Alberta, 2017, p. 14) (United States Environmental Protection Agency [USEPA], 2008, Section 0, pp. 6-7, 11-12) (USEPA, 2008, Section 0, p. 10) (R.M. Young Company, c)

3.1.6. Discussion

It's clear based on the standards above that a 0.5 m/s starting threshold is common and achievable. B.C. and Alberta specifically provide this guidance, while the USEPA, and by extension state agencies provide ranges starting at 0.5 m/s, thereby requiring sensor that can report at this wind speed. The Meteorological Service of Canada's automated sites do not provide as stringent a requirement, but is the only network above not focused on air quality monitoring. It should also be noted that the US National Weather Service (NWS) has replaced mechanical sensors with ultrasonics at all NWS/Federal Aviation Administration automated surface observation sites to address the impact of icing on the sensors (Fox, 2013, p. 10).

3.2. Client Outreach

The Ministry has undergone a minor reconfiguration since this project was first proposed, so the organizational chart has changed, but for stakeholders impacted by this project roles and responsibilities have remained essentially static. Table 6 provides an updated breakdown of the air program, with associated roles and responsibilities.

Table 6 - Condensed Responsibility Matrix - Air Program

Ministry of Environment – Condensed Responsibilities Matrix – Air Program				
Environmental Protection Division				**Environmental Sustainability and Strategic Policy Division**
Environmental Quality Branch	**Regional Operations Branch**			**Knowledge Management Branch – Environmental and Climate Monitoring**
Clean Air	**(MAS) Air Monitoring**	**(MAS) Air Assessment**	**(Compliance) Air Audit**	**Air and Climate Networks**
Air quality objectives	Station siting & installation	Specialist support to authorizations and compliance	Quality Assurance (field audits)	Capital and operational funding
Specialist support to Air Assessment	Instrument maintenance & calibration	Airshed assessment		Technology assessment and capital procurement
Air quality modelling		Air quality advisories		Monitoring standards & data validation
Provincial-scale reporting		Local government & public engagement		Data Management & systems administration
National-scale working groups		Regional-scale reporting		Climate network coordination across multiple agencies
				Provincial/national scale working groups

Adapted from *TMGT 8101 – Directed Studies – BC Air Quality Monitoring Program – Meteorological Monitoring Network Project Plan*. Wiederick (2017, p. 12)

Formal leadership teams within the air program are the leadership committee, and technical committee. The leadership committee is comprised of the directors Clean Air (CA), Monitoring, Assessment and Stewardship (MAS), Environmental and Climate Monitoring (ECMS) and Compliance's operations manager within the Regional Operations Branch who is responsible for the air audit team.

The leadership committee is responsible for setting the overall strategic aims of the program, and approves funding requests in coordination with a larger body responsible for all funding requests across all sampling media. Pending the outcome of this project, $40,000 has been earmarked to purchase new meteorological sensors.

The technical committee is comprised of the unit heads reporting to the leadership committee: two in MAS, one representative from CA, the unit head of Air and Climate Networks within ECMS and the operations manager leading the air audit team.

After discussion with the project sponsor, it was determined that consultation would only be required with the technical committee, rather than with the leadership committee to execute this project.

3.2.1. Method

Achievable standards aren't necessarily required standards, so data was gathered from our key clients: air quality meteorologists with the Regional Operations Branch, and the senior air quality meteorologist primarily responsible for the provincial modelling standards (Clean Air section). A multi-phased approach was used to invite comments and questions, and to specifically solicit important information.

Initial outreach was done via email, with a brief explanation of the project, and an attached condensed document outlining the initial assessment and methodology, which is largely comprised of section 2.0 of this report. A draft of this was first provided to one of our meteorologists to ensure form and content would meet the needs of the audience and edited as required. The note closed with a request for feedback to help outline network requirements, and a deadline for doing so; however, no feedback was received. Stakeholders were again engaged at a cross-agency meeting of meteorologists, where some feedback was gained, and a follow-up phone call was had with one stakeholder. Finally, a meeting was held with key stakeholders – an air quality meteorologist, the head of the Air Quality Assessment unit, and the senior air quality meteorologist.

This approach allowed for all interested stakeholders to have input based on availability and interest, and have targeted conversations with key individuals/decision makes. Questions were open-ended and intended to determine what outcomes were required, rather than a specific technology:

- What do you use the data for?
- What data do you require?

- Based on those requirements, are their specific Data Quality Objectives you need met?
- Is sensor performance as summarised something worth addressing?

The questions intentionally did not ask about specific technologies or possible improvements, but were aimed at helping to determine the purpose of data generation/collection. This drew on key elements of the Outcome-Driven Innovation (ODI) process, but did not strictly follow the method. ODI attempts identify key areas for innovation by soliciting feedback from customers to define the job that the product/service is used to complete, their desired outcomes, the importance of these outcomes, and their current level of satisfaction having these outcomes met. This data is filtered through a weighted scoring system to determine which areas are best targeted by innovation, and what that innovation needs to address (Asserio, 2012) (Bettencourt & Ulwick, 2008, pp. 62-68). This is usually determined through a series of interviews and surveys, but in this case the main data gathering exercise was a meeting with key stakeholders.

Stakeholders were invited to provide information to ensure the process was inclusive. Outcome-oriented questions were asked, and specific feedback was sought from key stakeholders and decision makers to ensure relevant data were captured. A traditional ODI approach was not taken for several reasons: it would have required much more staff time; the scope of the project is narrow and addresses prescribed methodologies; and, staff objectives may not be in alignment with organizational objectives.

3.2.2. Results

Feedback from users indicated data use is varied, but the primary uses heard were:

- the verification of modelling conducted for authorizations,
- providing real-time data during/prior-to air quality advisories or other air quality events; and,
- gaining a general understanding of local meteorology.

Users indicated that they required one hour averages of temperature, relative humidity, wind speed and direction, and sigma theta (σ_θ), which is “the standard deviation of the azimuth angle of the wind” (USEPA, 2000, p. 6-2) There was little support for a reduction in Data Quality Objectives (DQO), though it was recognised that roof-top towers can be problematic, and that data from these sites are not suitable for some purposes.

Potential additions to the network were also mentioned, but they fall outside the scope of this project, specifically sites able to generate sufficient data to drive models. This was described as requiring 20-30 m towers with measurements made at multiple heights, and other parameters added such as precipitation and total solar radiation.

3.3. Station site characterization

One factor impacting data quality is the instrumentation used for meteorological monitoring, but station siting is critically important when determining whether the data are, or will be appropriate for any specific use. To quote the EPA directly: “site selection is much more important than the proper placement of individual pieces of air monitoring equipment” (2008, Section 1, p. 14). Factors impacting measurement include buildings, towers, stands of trees, and topography. This project aims to incorporate site-specific factors in decision making to not only ensure that sensors meet the requirements of the site, but that the site can produce the desired data regardless of the instrumentation deployed.

3.3.1. Standards

Station siting is a difficult process – if a suitable site can be identified that will ensure representative data collection, field staff will then be tasked with balancing these attributes with the logistical reality on the ground: can ENV negotiate access with a land/building owner? Are required utilities available? As such, siting can become an exercise in compromise.

B.C. has only issued guidance for station siting in a limited manner by referencing USEPA standards in a guidance document for the proponents of new mining projects (BCMOE, 2016, p. 20). It has never been added to field sampling manual, or as the part of any other operational policy. It’s clear that significant effort was invested in the early 2000s to develop a document titled “Air Monitoring Site Selection and Exposure Criteria,” including detailed explanations of the effects of obstructions to air flow, but this document was never completed. The author’s/editor’s notes and incomplete sections are still found within the document, so its content is not being incorporated in this report.

As part of the B.C.'s Climate Related Monitoring Program (CRMP) some monitoring standards were compiled in 2011 to describe a common standard across participating agencies (e.g., ENV, BC Hydro, BC Ministry of Transportation and Infrastructure, BC Ministry of Forest, Lands, Natural Resource Operations and Rural Development, etc.). Although this document does not appear complete, the content has been discussed with the author, and is relevant to assessing this network. This document states that wind components will be measured at the industry standard of 10 m with "minimal impact by local obstructions (BCMOE, 2011)." Temperature and humidity are to be measured 1.5 m to 2 m above the ground unless impractical due to snowfall accumulation, or over vegetation that remains relatively static with documented distances from any sources of heat (BCMOE, 2011).

It should also be noted that B.C. has suggested, by referencing USEPA guidance, that data users should determine the instrumentation and siting criteria used when evaluating meteorological data for dispersion modelling (BCMOE, 2015, p.36). There are general principles that can be applied when evaluating factors such as tower height, though the following assumes simple terrain:

- Standard wind measurement is conducted at a height of 10 m; if there is vegetative cover on the ground (e.g., trees), the sensor should be 10 m above the top of the canopy (USEPA, 2000, p.3-4).
- Wind sensors installed on roof-tops need to avoid the aerodynamic wake created by the building, which is about 2.5x the height of the building (USEPA, 2000, p.3-4).
- Temperature and RH should be measured at 2 m, over a level area of short grass or representative ground cover no less than 9 m in diameter (USEPA, 2000, p.3-6). If obstructions are present the probe should be 4x the height of the obstruction away and at least 30 m from "large paved surfaces" (USEPA, 2000, pp.3-6, 3-7).

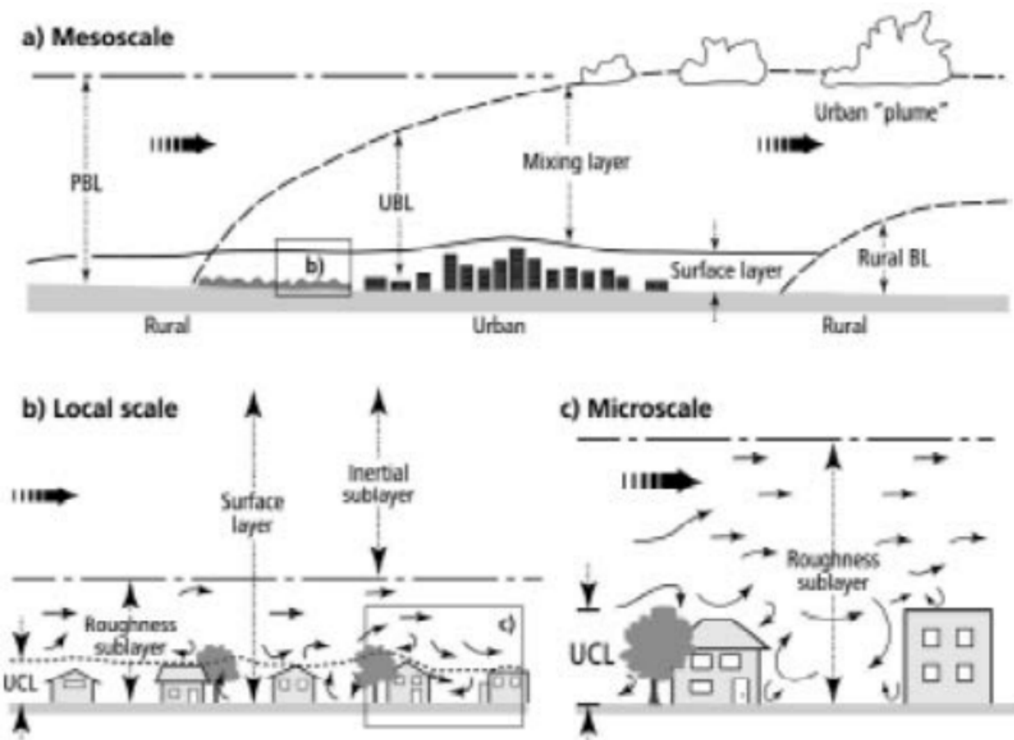
One instrument manufacturer, Vaisala, provides some simple guidance for siting, but also cautions users to reference World Meteorological Organization (WMO), or other applicable standards:

- The instrument should be higher than any other object within 300 m.
- The tower should be a distance 10x the height of any obstruction from it.
- Roof-top towers should be 1.5x the height of the building. If the diagonal distance across the roof is less than the height (i.e., the building is taller than it is wide), the tower should be 1.5x the diagonal distance (Vaisala, 2014, p.58).

Urban sites pose particular challenge, so roof-top sites are sometimes required, but the height of nearby buildings should be considered when determining sensor height (USEPA, 2000, p.3-12). As referenced by the USEPA (2008, Section 1, p. 15) the WMO has published initial guidance for siting stations in urban locations. This guidance is quite clear that absolute adherence to any guidance is impractical in urban areas. It is equally clear that roof-top monitoring should be avoided due to the extreme temperatures generated, and that wind speed and direction may be entirely different over the roof than at the same elevation away from the building unless "very tall" masts are used (Oke, 2006, pp. 1-2, 15).

As outlined by Oke, prior to establishing monitoring stations data users must define required data use and the necessary scale of representativeness. Spatially, stations can provide data at the microscale, local scale, or mesoscale. Measurement at the microscale are influenced by individual trees or buildings (Oke, 2006, pp. 2-4). Local scale monitoring provides data that are representative of an urban area with

Figure 8 - "Schematic of climatic scales and vertical layers found in urban areas"

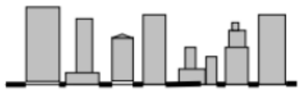


Adapted from *Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites.* Oke. (2006, p.3)

consistent land use and development, so is not unduly uninfluenced by individual objects at the microscale (Oke, 2006. p. 4). Mesoscale requires the integration of data from multiple stations to represent an entire city (Oke, 2006, p. 4) (see Figure 8). When installing stations within an urban environment the effects of surface roughness and the Urban Canopy Layer (UCL) should be considered.

Roughness is a function of the objects on the ground – trees, buildings etc. Urbanized environments will form distinct zones of relatively homogenous land-use: dense urban cores, residential areas etc. Oke suggests reviewing urban areas and classifying land-use types as "Urban Climate Zones" (UCZ); within these areas the effect of land use on observed meteorological conditions will be similar (see Figure 9)(Oke, 2006, pp. 9-13).

Figure 9 - "Simplified classification of distinct forms arranged in approximate decreasing order of their ability to impact local climate"

Urban Climate Zone, UCZ[1]	*Image*	*Rough-ness class*[2]	*Aspect ratio*[3]	*% Built (imperm-eable)*[4]
1. *Intensely developed urban with detached close-set high-rise buildings with cladding, e.g. downtown towers*		8	> 2	> 90
2. *Intensely developed high density urban with 2 – 5 storey, attached or very close-set buildings often of brick or stone, e.g. old city core*		7	1.0 – 2.5	> 85
3. *Highly developed, medium density urban with row or detached but close-set houses, stores & apartments e.g. urban housing*		7	0.5 – 1.5	70 - 85
4. *Highly developed, low or medium density urban with large low buildings & paved parking, e.g. shopping mall, warehouses*		5	0.05 – 0.2	70 - 95
5. *Medium development, low density suburban with 1 or 2 storey houses, e.g. suburban housing*		6	0.2 – 0.6, up to >1 with trees	35 - 65
6. *Mixed use with large buildings in open landscape, e.g. institutions such as hospital, university, airport*		5	0.1 – 0.5, depends on trees	< 40
7. *Semi-rural development, scattered houses in natural or agricultural area, e.g. farms, estates*		4	> 0.05, depends on trees	< 10

Key to image symbols: buildings; vegetation; impervious ground; pervious ground

Adapted from ***Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites***. Oke. (2006, p. 11).

Areas with few, small obstructions, or closely spaced and homogenous objects, like closely spaced buildings of similar height, will fall in a lower roughness class, while large objects of varying heights will be in a higher roughness class (see figure 9). The UCL height is described as "approximately the equivalent to the mean height of the main roughness elements" (Oke, 2006, p. 4). Wind measurements that occur within the UCL will represent microclimatic influences; however, once the blending height is reached these effects attenuate and the data may be representative at the local-scale (see Figure 8) (Oke, 2006, p. 4). Estimates of blending height can be 1.5x UCL to >4x UCL depending on surface roughness: as stated by Oke a dense, uniform urban area will be at the lower end of the scale, while a low density area will be at the higher end (2006, p. 4).

Oke makes several practical recommendations:

- Areas bordering different UCZs should be avoided (2006, p.14).

- Avoid rooftops – wind, temperature and RH data can be severely compromised without "very tall masts" (2006, p. 15). Oke cites earlier work that proposes wind sensors be "at a height greater than the maximum horizontal dimension of the major roof" (2006, p.24).
- Stations should be sited in spaces that are consistent with UCZ – choose an open space where the aspect ratio, which is the average obstruction height divided by the average spacing, is consistent with the UCZ (2006, p. 11, 16).
- Temperature and humidity should be measured over average surface cover for UCZ and spaced at an average aspect ratio; measurement height can be a fewer meters higher than normal if required as it will have minimal impact. Avoid measuring temperature on rooftops – if necessary the sensor should be at least 1.5x UCL, but the data may still not be representative of temperature at 2 m (2006, p.17).
- In areas typical of UCZs 6-7 (see Figure 9) a 10 m tower may work if standard siting guidance is followed: 10x the height of the obstruction from the tower; obstructions generally shorter than 6 m (2006, p.24).
- If development is more dense tower height should be the higher of 10 m or 1.5x UCL; if tall buildings are present, but sparse, then the wake zone created by the buildings needs to be avoided; and, avoid wind measurements in dense areas with lots of high-rise buildings unless sufficiently high towers can be used (2006, pp. 24-25).

While the above is not an exhaustive summary of that guidance, it provides a good starting point to assess the siting of many stations in B.C., which should inform data use, and ultimately the technology required to be deployed.

3.3.2. Site Assessment

Figure 10 - Vernon Science Centre Meteorological Tower Location.

Adapted from Google Earth Pro (2018). Image RDNO. April 23, 2013. Elevation 537m.

Initial site assessments were done via Google Earth and Google Street View where images were available, and where possible a virtual "walk-around" the area was also completed. The Ministry's internal "station start-up forms" were also reviewed though they contain a limited amount of meta-data. Station information was added to the previously compiled station matrix including urban climate zones, and summarised in Appendix C. Where site location could not be confidently identified, limited data are recorded. Google Earth's measuring tool was also used to estimate distances to buildings, changes in land use, and the size of roofs where required.

Potential siting influences are identifiable such as location within a specific UCZ, the proximity to other UCZs, the buildings towers are mounted on, and an estimation of the height of the UCL. As an example, Figures 10 and 11 show the station located at the Vernon Science Centre. This site is near the border between two different zones: UCZ 4 (shaded red) to the north and west, with UCZ 5 (shaded blue) to the east/north-east, and park to the south which is a large anomalous feature. This site does not seem to align with the guidance from Oke above. The tower is about 6 m above a lower section of roof, but is on a large building with a peaked section to the east. The building itself is two to three stories, so a 6 m tower is below the recommended height if following any of the guidance in the previous section.

Other sites, such as Terrace are likely less impacted by microscale influences (see Figure 12): a ground

Figure 11 - Vernon Science Centre Urban Climate Zones

Adapted from Google Earth Pro (2018). Image RDNO. April 23, 2013. Elevation 2.98km.

Figure 12 - Terrace Air Quality Station Location.

Adapted from Google Earth Pro (2018). Image DigitalGlobe September 1, 2013. Altitude 4.14km.

based 10 m tower is situated within a residential area. The town is small, so it is by default close to other UCZs, but siting here is likely as good as is going to be found in communities this size.

3.4. Discussion

Of the 27 sites operating, 15 are roof top and of these sufficient data could be gathered online for nine sites. As outlined above the USEPA states that the depth of the wake created by buildings is 2.5x building height, so sensors need to be installed at least 1.5x building height to be above this. This makes some rooftop locations problematic; however, if following Oke's suggestion that tower height be greater than the diagonal distance across the roof, then many wind instruments are not mounted high enough: the Ministry has generally installed 10 m towers, and has used large, multi-story buildings in many locations. These include school roof tops in Prince Rupert and Prince George, large buildings like Vernon Science Centre and Prince George Plaza, or industrial facilities like Prince George Pulp.

Many Ministry sites are in lower density residential or commercial areas. Stations in UCZ 2 are the exception: roof-top sites at Victoria Topaz and Prince George Plaza. UCZ 4-6 are more common, with Grand Forks Airport likely the only site that meets standard siting criteria of having obstructions to air flow 10x the height of the obstruction away from the tower. In many locations the dominant features are 3 m to 6 m, one to two story buildings infilled with trees. At these sites ground-based 10 m towers may be getting above the UCL: Merritt, Courtenay, Cranbrook, Terrace, etc.

This project cannot determine whether any individual site is suitable for all potential uses, so professional judgement must be made by meteorologists when selecting new monitoring locations or data for a specific use. Future investment in monitoring technology should reflect the relative value of the data being generated by an individual site for its primary intended use. If an investment is to be made in the network, roof-top sites should be addressed last as they may be heavily compromised by the buildings they are mounted on. This recommendation is a generalization, so ad-hoc evaluation of specific sites may demonstrate that investment is warranted.

4. Technology Assessment

This section will focus on wind instrumentation as temperature and RH measurement are not seen to be problematic. As stated, three ultrasonic sensors were purchased for testing – these were selected based

Figure 13 – Gill WindSonic M.

Adapted from Gill WindSonic M. Gill Instruments. (2017). Retrieved from: http://gillinstruments.com/data/datasheets/WindSonicM-1405-0029-iss10%2003102017pdf.pdf

Figure 14 – Vaisala 701

Adapted from WINDCAP Ultrasonic Wind Sensor WMT700 Series. Vaisala. (2017) Retrieved from https://www.vaisala.com/sites/default/files/documents/WMT700-Datasheet-B210917EN-J.pdf

Figure 15 - R.M. Young 86004

Adapted from Campbell Scientific Canada (2018). Retrieved from https://www.campbellsci.ca/86004

on price-point, and meeting or exceeding the performance specifications of the R.M. Young 05305. There sensors are: the Gill WindSonic M, the Vaisala 701, and the R.M. Young 86004 (Figures 13 – 15).

Ultrasonic anemometers work by measuring the transit time of an acoustic signal across a known distance – wind speed and direction will predictably impact the time it takes for the signal to move from source to detector, so wind variables can be calculated (USEPA, 2008, Section 2, p. 3).

4.1. Ultrasonic Sensor Assessment

4.1.1. Method

The instruments were evaluated using a Collocated Transfer Standard (CTS) as outlined by the USEPA (2008, Section 2, pp. 18-19). This test compares the data between a standard and a subject instrument. In this test the standard was an R.M. Young 05305 with current certification, and the subject instruments were the ultrasonic sensors. This provided both a means of verifying the instruments and an opportunity to evaluate a method that could be applied to audit ultrasonics in-situ should they be deployed.

The USEPA provided some results from their trial of the method. For their test, a 4 m roof-top tower was deployed with the sensors approximately 1 m apart (2008, Section 2, p. 21). Their results did not meet the suggested standard, but they speculated that this was due to increased turbulence as they used a short, roof-top tower, and that they used a 5 minute averaging period rather than a 20 minute averaging period used in previous research (2008, Section 2, p. 21). The USEPA also stated that another published test did not quite meet the suggested standard, but a 15 minute averaging period was used (2008, Section 2, p. 22).

Table 7 - Sensor Installation Distances – Test Configuration

Sensor	Height	Horizontal Distance from Reference
R.M. Young 05305	5.74 m	-
R.M. Young 86004	5.76 m	1.07 m
Vaisala 701	6.00 m	2.00 m
Gill WindSonic M	5.60 m	3.56 m

The instruments were mounted as per Table 7 above. This met the USEPA's guidance to be no more than 10 m away from the standard horizontally, and within the lesser of 1 m or 1/10 of the standard's height from the ground (USEPA, 2008, Section 2, p. 18). All sensors were above tower height.

The datalogger operated at a 1 second scan rate, and data were averaged over multiple periods: 5 minutes, 15 minutes and 20 minutes. Pass/fail criteria for the test were based on USEPA's recommendations as per Table 8. It was suggested that values over 1 m/s be compared, and that one diurnal cycle, 24 hours, was the ideal period for comparison (USEPA, 2008, Section 2, p. 19).

Table 8 - Recommended Criteria for CTS Audit

Wind Variable	Average Difference	Standard Deviation of the Differences	Qualifications
Speed	±0.25ms <5ms or 5% or <2.5ms above 5ms.	0.2ms	Wind speeds > 1ms
Direction	+/- 5^{o}	2^{o}	Wind speeds > 1ms

(USEPA, 2008, Section 2, p. 23)

4.1.2. Field Test

The original test plan called for the field testing to be undertaken at the Duncan air quality station (Wiederick, 2017, p. 20); this was not possible as a required site move was delayed due to a staff shortage. A new test site was identified at ENV's North Rd. Lab in Saanich – the snow monitoring program intended to install a tilt-over tower for testing of their equipment, so support was provided to the snow program to help install the station early, providing an accessible test location as pictured in Figure 16.

A Campbell Scientific CR3000 with current certification was programmed and installed in an outdoor enclosure with cell modem and 24 VDC power supply that provided operating power for the ultrasonic sensors.

- All instruments were bench tested in the lab to test communications and ensure the program was functioning as intended.
- Extension polls were made from spare tubing to elevate the sensors well above tower height to avoid eddies or changes in wind conditions caused by the tower itself.

Figure 16 - Test Tower at North Road Lab

Once the above were completed the sensors were mounted with the boom at ground level to allow for sensor alignment to North. The boom was then secured in its mounting tube and the tower raised into position. There was some movement of the sensors initially after start-up, so the direction data were corrected based on estimated sensor alignment using a compass and a smartphone theodolite application. This proved to be too inaccurate for the test, so the sensors were realigned with the end of the boom as "North" and the test was re-run. True alignment with North is irrelevant for this test, but the alignment of the sensors relative to each other is critical.

To remove other possible sources of error:

- The signal cables were cut to their minimum possible length on the Gill and R.M. Young 86004 to avoid signal loss. These transmitted 0-5 VDC signals, while the Vaisala 701 output a 4-20 mA signal.
- A ground-plate was installed to provide an independent ground for the logger.
- The R.M. Young 86004 was configured to use differential inputs on the logger rather than single ended inputs which are common in Ministry installations. This was done as recommended by the instrument manual (Campbell Scientific (Canada) Corp, 2015, p. 17).

Finally, to address data loss that occurred in the initial test period a cellular modem was added to the site to permit automated daily data collection to avoid data loss. The cause of data loss was never identified.

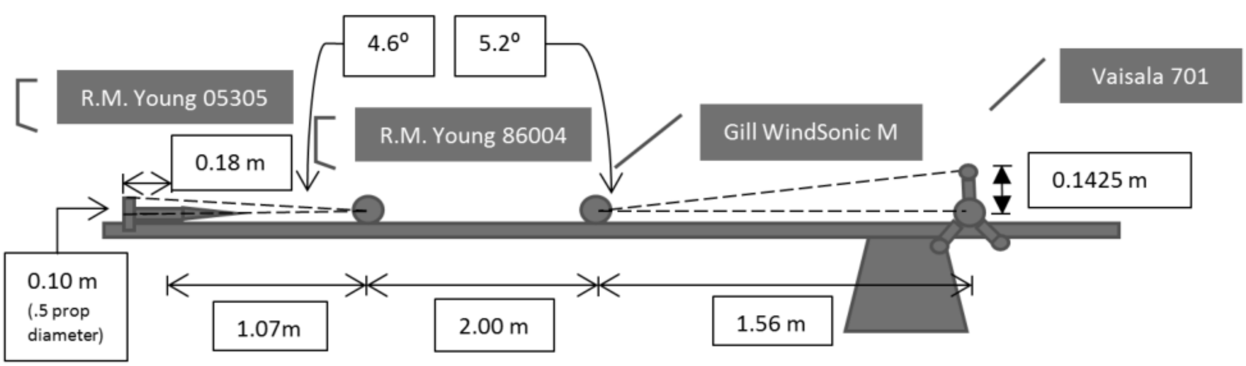
4.1.3. Data Validation

Prior to analyzing sensor data ENV's data handling rules were reviewed referencing the recently drafted *Standard Operating Procedure for Ambient Air Quality and Meteorological Data Validation* (2017) and discussed with the Air Data Quality Assurance Specialist to confirm the rule-set for data acceptance. Additionally, winds measured from directions that may be impacted by sensor-to-sensor interference were removed as per Figure 17 below.

Validation rules were as follows:

- Graph and visually review scalar speed and vector values and the wind direction sigma value (standard deviation of the wind direction).
  - Invalidate persistently flat-lined data. Only data above 1 m/s were used, so this wasn't an issue.
  - Review minimum and maximum values: outliers can indicate sensor or signal transmission error.
- Remove data where:
  - average wind speed is under 1.0 m/s as measured by the reference sensor;
  - average direction is between 355⁰ and 360⁰ (the dead band of the reference sensor) as measured by any sensor;
  - average direction is <5⁰ as measured by any sensor;
  - average direction is ≥174 and ≤186 as measured by any sensor; and,
  - sigma (σ) = 0. This is standard deviation of the wind direction over the averaging period.

Figure 17 - Top-view - Test Tower Configuration



4.1.4. Data Analysis

The test site was relatively sheltered by a stand of trees to the south and not subject to more intense near-shore winds as it was in the middle of the Saanich peninsula. This meant that calm or near-calm winds were the norm (calm = <0.5 m/s), so to ensure a sufficient data set the test period was extended. Data from May 10 – 22nd were compiled and screened; the remaining data analyzed represented 24.5 hours of 5 minute averages, 23.25 hours of 15 minute averages, and 24 hours of 20 minute averages.

Speed and direction were evaluated by subtracting the reference sensor average measurement from the instrument being tested (USEPA, 2008, Section 2, p.23). The standard deviations of the differences were calculated for comparison to the values in Table 8.

The results of the test, with the green values being those within the acceptance standard are compiled in Table 9 below.

Note: the "701 corrected" column represents data that were adjusted to account for signal error not accounted for in the datalogger's program. The 250Ω resistors used to convert from a current to voltage signal on the datalogger had actual values of 250.8Ω (wind speed) and 251.2Ω (direction) which would have biased the readings high by causing a slightly increased voltage drop across the terminals. If this approach is used for subsequent deployments this can be compensated for with appropriate scaling factors, or higher-tolerance resistors.

Table 9- Ultrasonic Colocation - Summarised Test Results

	Speed (m/s)				**Direction (°)**			
5 minute average; wind speed >1.0 m/s								
	701	**701 Corrected**	**Gill**	**86004**	**701**	**701 Corrected**	**Gill**	**86004**
Average	0.180	0.174	0.205	0.106	2.528	1.784	-1.693	-1.608
Std dev	0.065	0.065	0.058	0.035	2.985	2.943	2.231	1.459
15 minute average; wind speed >1.0 m/s								
	701	**701 Corrected**	**Gill**	**86004**	**701**	**701 Corrected**	**Gill**	**86004**
Average	0.185	0.180	0.206	0.107	2.402	1.677	-1.539	-1.746
Std dev	0.041	0.041	0.040	0.024	2.434	2.400	1.632	1.142
20 minute average; wind speed >1.0 m/s								
	701	**701 Corrected**	**Gill**	**86004**	**701**	**701 Corrected**	**Gill**	**86004**
Average	0.186	-0.180	0.206	0.108	2.492	-1.760	-1.598	-1.647
Std dev	0.039	0.039	0.033	0.020	2.368	2.317	1.501	0.993

All sensors performed relatively well, with all sensors falling within specification for wind speed at all averaging periods. The Gill and R.M. Young ultrasonic sensors met all criteria when comparing 15 minute and 20 minute averages, with the Vaisala falling just outside of the stated tolerance. It's unclear whether the Vaisala 701 did not perform as well as the other sensors due to measurement error, or because it was furthest from the reference sensor. Future instrument deployments will help to determine the cause of the discrepancy.

Scatter plots of the 20 minute data are available in Appendix D; this includes the raw data, including graphs and scatter plots at multiple time bases.

4.1.5. General Observations

All sensors were relatively easy to install, but there were issues that could largely be resolved by crafting specific requirements in any subsequent procurement effort:

- Soldering the Gill cable connectors was time consuming, and there were insufficient conductors for all signal transmission and heater power. All instruments should be specified with a pre-made cable with all required connections at a nominal length (12 – 15 m).
- Not all instruments were supplied with external DC power supplies – this must be included in any future requisition.
- All instruments must come with anti-bird device (spikes or cage) and a bracket suitable for attachment to 1" NPT pipe which is standard on all installed towers.

Other observations relate to ease-of-use:

- The Vaisala is large and heavy, making installation cumbersome.
- The Gill does not have sufficient markings to easily verify north-alignment from the ground. Some manufacturer labels on the bottom seem to align south, but the alignment notch in the sensor body is too small.
- The R.M. Young is easiest to install – it will readily adapt to all towers as the lower-assembly of the unit is almost identical to the 05305, so integrates with our existing alignment collars. Wiring is simplest to troubleshoot and replace as there are no special connectors, and the heater

power wires were integrated into the cable. The instrument has a simple, highly visible south-aligned junction box with colour-coded terminals.

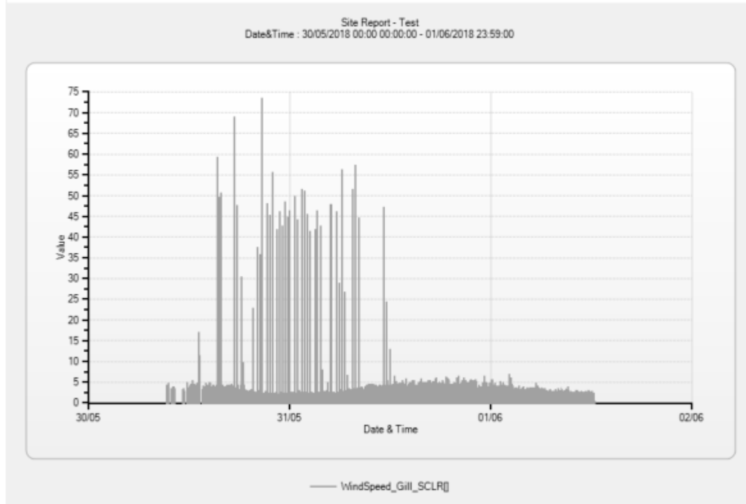
4.1.6. Envidas Ultimate Test

Figure 18 – Tripod Configuration at North Road Lab

The field test demonstrated sensor function, but it needed to be established that the sensors would interface with our PC-based logging systems as well as Campbell Scientific loggers. Temperature and RH probes needed to be tested as well, as all parameters must be logged on a single device to be able to reduce the amount datalogging equipment at stations. Once the field test was complete the sensors were relocated to a tri-pod outside ENV's North Road lab and wires fed into the building as pictured in Figure 18.

In this case the measurement accuracy of the sensors was not being evaluated, so sensor positioning was irrelevant, rather the intent was to prove communications worked. An EU logger was configured and DB-9 connectors soldered to the signal cables to enable RS-232 communications. Generally, each instrument required to connect to an EU logger requires a driver supplied by the vendor to enable data transfer. In this case existing R.M. Young and Gill protocols could be used. The Vaisala was able to be configured to push an ASCII (American Standard Code for Information Interchange) string, so the logger's "CustomPush" protocol was used and configured to gather the correct variables as recommended by the Air and Systems Data Management Specialist. No major issues were encountered with communications; however, some minor modifications were needed with the Gill to remove spiking from the data trace – reducing the scan rate to 2 seconds from 1 second stopped what was assumed to be cross-talk between the channels (see Figure 19).

Figure 19 - Spiking on the Gill WindSonic M Wind Speed Trace - Resolved Once Scan Rate Lowered to 2 s



The existing Rotronic temperature and relative humidity probes were also tested – this was not successful. Though they are able to be configured as MODBUS over RS-485 devices we were unable to get the sensor to respond, and eventually had to return the unit to the distributor for reconfiguration. At the time of writing this report we were waiting for the sensor to be returned.

Other options were available: when the Ministry selected the Rotronic HC2-S3 to replace the Vaisala HMP45C, the Vaisala HMP155 was also tested. There are no known issues with these probes, and it is believed the decision to go with Rotronic was strictly cost. Two were in storage, so one was tested using an RS-485 to RS-232 converter at the logger. As with the Vaisala 701 the sensor could simply be configured to push an ASCII string and EU configured to select the correct variables. There were no observed issues with instrument communications, though the cable supplied by Campbell Scientific did need to be modified to allow connection to the serial-output pins rather than analog. The Vaisala probe provides a good option for the Ministry, as it is less expensive than the Rotronics HC2-S3 if a serial-enabled device is required. The Rotronic probe is less expensive if only analog outputs are needed. Whether adoption of sensors with serial communications provides a savings to the Ministry will be explored in later sections of this report.

4.1.7. General Observations

There were differing levels of ease-of-use with sensor set-up for datalogging:

- Gill set-up was seamless. Once the wiring connections were made it was easy to configure the logger.
- The R.M. Young needed a few changes in its configuration to enable communications. This should have been possible with the manufacturer's software, but after consulting with vendor

support for EU it became apparent that all commands must be sent via HyperTerminal or similar terminal program as the R.M. Young software was problematic.

- Communications were not an issue with the Vaisala 701 once a minor wiring issue was sorted out, and a custom ASCII string configured. Vaisala provides an extremely flexible platform as the data output can be easily customized.

4.2. Other Available Technologies

As stated in the project plan, there was a desire to test ultrasonic sensors as they provide an opportunity to go to a low-maintenance sensor, but also recognition that there are other available technologies on the market (Wiederick, 2017, p. 17).

The three main types of wind instruments available are cup-and-vane, prop-and-vane, and ultrasonic, with the latter being the newest.

The Ministry has operated cup-and-vane anemometers and continues to do so in some limited applications – usually as an add-on component to a PM monitor for short-term studies; however, the data have limited application as instrument heights will likely be a non-standard 2-3 m above ground.

To be complete, two cup-and-vane instruments were investigated: the Met One 01C wind speed and 02C wind direction sensors, and the Vaisala Wind Set WA 15. Met One markets the 01C/02C as meeting "U.S. EPA … performance specifications for critical measurement applications" (Met One Instruments Inc., 2010, p. 1); Vaisala lists the WA 15 as "the industry standard in the wind sensor market" (Vaisala, 2018).

Quotes were requested from vendors, and specifications were noted referencing both the R.M. Young 05305 and USEPA specifications for meteorological monitoring for regulatory modelling. These are recorded in Table 10 below.

The Met One 01C/02C uses an optical chopper wheel to create a pulsed output to determine wind speed, and a potentiometer as the transducer for direction (Met One Instruments Inc., 2010) (Met One Instruments Inc.). As it is mechanical, it also has bearing sets that require replacement. Met One provided a range of maintenance intervals: 6-12 months, depending on the environment it is deployed in, with a factory rebuild recommended for every 12-24 months, so it does not seem to provide an advantage over our existing instrumentation (Met One Instruments Inc.).

Table 10 - Alternate Sensor Characteristics

Instrument		EPA Modelling Quality Data	RM Young 05305	Met One 010C/020C	Vaisala WA15
Wind Speed	Ranged	0.5 - 50 m/s	0-50 m/s	0-60 m/s	0.4 - 75 m/s
	Accuracy	±0.2 m/s	±0.2 m/s or 1% of reading	+/- 0.07 m/s or 1% of reading	±0.17 m/s @ 0.4 - 60 m/s
	Resolution	0.1 m/s	0.1 m/s	<0.1 m/s	
	Threshold	0.5 m/s	0.4 m/s (.9 mph)	0.22 m/s	0.5 m/s
	Distance Constant	≤ 5 m	2.1 m	1.5 m	2.0 m
	Range	0-360	0-360 (5° deadband)	0 - 357°	0 - 360°
Wind Direction	Accuracy	±3°	±3 degrees	±3°	±3°
	Resolution	0.5°		<0.1°	±2.8°
	Threshold	≤ 5 m/s @ 10°	0.5 m/s	0.22 m/s	< 0.4 m/s
	Damping Ratio	0.4 - 0.7	0.45 m	0.6	0.19
	Delay Distance	≤ 5 m	1.2 m	0.91 m	0.4 m
Other	Heating		n/a	yes	yes
	Temp		-50C to 50C	-50C to 65C	-50C to 55
	Output		analog	analog (voltage)	analog
	Secondary Output		n/a	n/a	RS-485
	Comments:		current unit	Quote in USD; used list price; 6-12 month maintenance interval. Did not include mounting arm/bracket.	Holds calibration for one year; moderate rain 2 years. Check once annually.
	Cost		**$2,492.50**	**$1,515.00**	**$3,750.00**

(Met One Instruments Inc., 2010) (Met One Instruments, p. 7) (Vaisala, 2017) (Vaisala, 2002a, p. 15) (Vaisala, 2002b, p. 15) (Campbell Scientific Canada, 2018) (USEPA, 2000, p 5-3) (USEPA, 2008, Section 0, pp. 13-14)

The Vaisala WA 15 uses optical methods to transform the mechanical movement of the sensors, but is more expensive, and does not seem to meet the USEPA suggested performance specifications for wind direction resolution (see Table 10); however, it guarantees operation within its performance specifications for at least 12 months, and up to 24 months depending on deployment conditions (Vaisala 2002a) (Vaisala 2002b). While it has an improved maintenance cycle, it doesn't seem to meet USEPA specification for meteorological modelling purposes. In fairness, R.M. Young doesn't provide a value for wind direction resolution for the 05305, but the sensor uses a potentiometer, so it provides very fine resolution.

These sensors were not tested within this project – these are a mature technology so there is little utility in comparing performance to a known standard, instead, questions surrounding these instruments come down to whether they provide a cost, maintenance or performance advantage. This is difficult to assess given the breadth of environments that instruments are exposed to in B.C. such as salty coastal environments, the cold of north-east B.C., or the heat of the southern interior. The Met One sensor does not seem to provide an advantage with respect to maintenance intervals, and the Vaisala does not meet the resolution requirements for wind direction measurement. This information was presented to the project sponsor, and it was decided to not evaluate different mechanical sensors further, rather to focus on ultrasonic options.

5. Business Case Analysis

5.1. Requirements

As indicated in earlier sections, performance requirements were confirmed as meeting the existing standard, which is aligned with USEPA requirements for modelling applications; the specifications of the ultrasonic sensors tested meet this standard.

A follow-up discussion was also had with both air unit heads at a technical committee meeting to determine what other objectives exist, and their relative importance. From this it was determined that cost control was important, but that reducing the staff time required to operate the network was also important, more so than standardization. This is an important point, as it is counter to the original project to replace the temperature and RH devices as well as the dataloggers where the main driver was standardization – the least important outcome as now defined.

Options were evaluated based on meeting required performance specifications, and on time and cost requirements as per the feedback received. The use of roof-top towers was also factored in as these sites should not necessarily be maintained to the same standard unless it can be determined that the data produced are sufficiently spatially representative, or that different technology lowers overall costs to the Ministry.

A status quo analysis was done to provide a benchmark to evaluate other options; however, this is not presented as an option within this report as the network will not meet its Data Quality Objectives (DQO). All other options are expected to bring data quality in-line with the DQO either across the entire network, or at sites that are less impacted by microscale influences as outlined below.

5.2. Options Analysis

5.2.1. Assumptions

Assumptions and constants for all analysis were:

- The station at Ainsworth is likely going to be shut down, so is not included in the analysis.
- All options were based on a five-year operational period to match the amortization period for equipment under $5000.
- Technician wages were estimated at a flat rate of $41.07 regardless of seniority (Province of British Columbia, 2018a). This is the average wage for a Scientific Technical Officer (STO) 21, which is the current classification for all regional air technicians. A multiplier of 24.8% was applied to the average hourly wage as this is how employee benefits costs are currently estimated.
- An extra $1000 was added to the cost of servicing Smithers, Houston and Telkwa given that they require bucket-truck access (estimate based on discussion with regional staff).
- Equipment costs were based on current quotes or recent purchases unless otherwise noted (as such sources are not provided). Where required foreign exchange was 1.32 Canadian to U.S. dollars. (Google, 2018)
- GST is not factored into costs as the Ministry is GST exempt; PST is not factored into costs where suppliers will not charge it (e.g., Alberta).
- Travel:
    - travel times were based on Google search as noted in Appendix E;

  - per diems were charged as government policy (Province of British Columbia, 2018b) (Province of British Columbia);
  - accommodations costs were based on current business travel rates as noted in Appendix E (Province of British Columbia, 2018d);
  - multi-site routes were chosen where appropriate – see notes in Appendix E, alternate routes were also designated depending on chosen option;
  - travel costs were halved to apportion some cost to work done at near-by or collocated ambient air monitoring sites on the same trip; and,
  - there is no accepted way to incorporate vehicle costs for travel to sites. Neither management nor fleet services could provide insight on this issue: these expenditures are rolled up to a high-level within branches, so there is no value or number used to apportion the cost of a fleet vehicle to a specific program. Using the federal government mileage reimbursement rate was discussed, but it is likely overestimating actual costs.
- Maintenance costs for temperature and RH probes were not factored in as they will remain static regardless of the option chosen.
- Maintenance costs for ultrasonic sensors were based on average wind-tunnel testing pricing as provided by each supplier.
- Maintenance time:
  - R.M. Young 05305 maintenance-time is estimated as 2 h per site visit – this includes conducting maintenance and generating documentation.
  - Ultrasonic sensor maintenance-time is estimated as 1.5 h per site visit – this includes conducting maintenance and generating documentation.
  - Installation of new equipment, in most cases, is not going to take a lot of time. The estimates above are generous, so extra time spent installing a new sensor or running cable will likely be absorbed into the total time allocated over five years, that said contingency time will be built into any deployment plan
- Available equipment was based on the inventory listed in Table 11 below; all capital requirements integrate existing inventory. This count does not include upgrading Ainsworth as the site will likely be shut down.
- Station configuration is as per Table 12 below. Table 12 outlines which stations use roof-top towers, and which can integrate meteorological sensors with an existing EU logger.

Table 11 - Currently Available Equipment

Equipment	Deployed	Available
Vaisala HMP45C	20	-
Vaisala HMP155	0	2
Rotronic HC2-S3	7	10
RM Young 05305	27	19
CR 21x	9	2
CR 23x	5	2
CR 1000	12	5
CR 3000	1	2

Table 12 - Stations by Tower Type

Can Integrate; Ground-Based Tower	Can Integrate; Roof-Top Tower	Can't Integrate; Ground-Based Tower	Can't Integrate; Roof-Top Tower
1. Colwood	1. Burns Lake	1. Grand Forks	1. Prince George Glenview
2. Courtenay	2. Houston	2. Merritt	2. Prince George Pulp
3. Cranbrook	3. Kelowna	3. Telkwa	3. Prince Rupert
4. Duncan	4. Prince George		4. Quesnel Cariboo Pulp
5. Farmington	5. Quesnel Secondary		5. Stewart
6. Smithers	6. Vernon		6. Valemount
7. Squamish			7. Vanderhoof
8. Williams Lake			8. Victoria Topaz
9. Terrace			9. Golden

5.2.2. Status Quo

First, the costs associated with maintaining status quo operations were analyzed to provide a baseline to compare all other options to. This included moving forward with the Ministry's previous plan that required:

- Allocation of all available equipment to the meteorological network to standardise with the CR1000, Rotronic HC2-S3, and the R.M. Young 05305.

- Capital funding to purchase sufficient dataloggers and probes to update all existing sites including four spare loggers and four spare HC2-S3 probes.

Based on this, capital costs would be approximately $52,500 requiring $10,500 per year from the program's amortization budget. Operating expenses would equal just over $52,500, and require about $44,500, or just fewer than 1100 hours of staff time over five years.

5.2.3. Option One – Maintain Current Instrumentation

The first option is to maintain the same instrumentation with an accelerated maintenance cycle to achieve better network performance. This requires the same $52,500 capital investment as per the status quo summary above.

R.M. Young's suggested maintenance cycle, if aiming for accuracy of ± 0.3 m/s and ± 0.3^{o} (which are close to the requirements in Table 5) are:

- Every three months blow on vane and prop to look for irregularities; drive the shaft with an anemometer drive at a mid-range value, and check alignment with a known point or the marks on the sensor's housing (R.M. Young, a, p 1-3).
- Every six months remove the sensors from the tower and measure torques, low and mid-range wind speeds with an anemometer drive, check the vane's balance, and check direction at 30^{o} intervals (R.M. Young, a, p 1-3).
- Every year conduct laboratory checks: this includes many of the checks as above, but requires monitoring the speed output with an oscilloscope, and verifying the direction output at more points nearer to the instrument's dead-band (R.M. Young, a, p 1-3).
- Every two years return the instrument to the manufacturer for wind tunnel tests and verification of starting and stopping thresholds, as well as direction outputs across full 360^{o} of movement (R.M. Young, a, pp. 1-3).

This is clearly well beyond what ENV currently conducts, so a rough cost estimate was based on status quo and a few other pieces of information:

Campbell Scientific has advised that wind tunnel testing of the 86004 costs $620, so it's assumed this would be approximately the same for a mechanical sensor, and would be required twice within five years for each of the 28 stations. Additional instrument checks at three-month intervals would cost the same as the six-month checks at $6,327.28 per cycle. These two items increase operational costs to $197,068.28 over the same period, but this is low as it is probable that failing components would be identified earlier, leading to more repair costs. This represents at least an additional $98,000 in operating costs and technician time as per Table 13 below. Given that each maintenance interval includes about 110 hours of technician time, doubling frequency from six to three months would require an additional 1,100 technician hours.

Table 13 - Option One Operational Costs

Operations costs	**Cost**
Current Maintenance Cycle	$97,022.78
Additional 10x site visits (FTE)	$44,452.78
Additional 10x site visits (Operational)	$18,820.00
Wind Tunnel Testing (x56)	$34,720.00
	195,015.56

5.2.4. Option Two – Replace all Wind Sensors with Ultrasonic Instruments

The second option would see all R.M. Young 05305 replaced with an ultrasonic sensor, as well as installing a Vaisala HMP155 at sites with a collocated EU logger, plus two spare HMP155 and four spare ultrasonic sensors. This frees up all available CR1000 and HC2-S3 instruments for stand-alone sites where integration with EU datalogging equipment is not possible, leaving three spare loggers and HC2-S3 probes. To acquire new equipment the Ministry would need to post an “invitation to quote” to the government procurement website with strict specifications, so it’s not possible to know precisely which model would be purchased. For this exercise the average cost of the Gill WindSonic M, Vaisala 701, and RM Young 05305 including accessories was used, as well a recently quoted price for the Vaisala HMP155.

There are operations costs associated with ultrasonic instruments: Vaisala recommends that the unit be checked with its “verifier” annually to ensure the transducers are still aligned properly, though they state that the unit requires no calibration, and the verifier check seems to be optional (Vaisala, 2014, pp. 163-166). Gill states that there are no service or maintenance requirements for the instrument, but that calibrations are available on request. It is possible to conduct an alignment test like the one recommended by Vaisala as outlined above using the box the instrument was shipped in. (Gill, 2016, pp. 53-55). R.M. Young provides no specific calibration or maintenance tasks.

Further guidance can be taken from Alberta's AMD where monitoring requirements have been codified. The AMD requires that ultrasonic sensors be factory calibrated at least every two years, and inspected once per year to ensure proper heater functioning, that bird-spikes are still in place, and that measurement is occurring (Government of Alberta, 2016, pp. 22-23).

In practice, ensuring functionality can be done remotely as the Ministry checks data hourly, and technicians should already be in the habit of visually inspecting their wind equipment when attending any site to ensure that birds have not damaged the propellers. It's not clear that the annual check is providing much value, but it has been priced into this option as well as an average cost of calibrating ultrasonics based on recent quotes.

Equipment deployed would be as per Table 14 below. This option requires approximately $142,000 in capital plus $53,500 operational funding over five years. Required staff time would drop from approximately 1100 hours under a status-quo system, to just over 470 hours due to a reduced maintenance interval, and less time on-site as there is less work to do.

Table 14 - Option Two Equipment Distribution

Equipment	Deployed	Available
Ultrasonic Sensor	27	4
Vaisala HMP 155	13	3
Rotronic HC2-S3	14	3
CR 1000	13	4
CR 3000	1	2

At the Ministry's discretion, it would be advisable to conduct some CTS audits at a few easily accessed sites to determine whether instrument performance is decaying over time. This also allows for an evidence-based approach to service intervals rather than an arbitrary two-year cycle. The CTS audits could be done during regularly scheduled visits using the existing Ministry stock of R.M. Young 05305 sensors.

5.2.5. Option Three – Limited Ultrasonic Deployment

Option three provides a blended approach to factor in station siting: update only the ground-based towers, and leave the R.M. Young sensors at roof-top locations – this essentially re-states the DQOs as meeting existing requirements, but only where station siting makes this appropriate. This requires fewer capital requirements, but it is anticipated that ongoing dialog with program staff could lead to specific stations being identified for upgrades in the future. A few variants on this deployment were explored and outlined as options 3a to 3c below. All have the same capital requirements, so equipment deployment would be as per Table 15 below.

Table 15 - Option Three Equipment Distribution

Equipment	Deployed	Available
Ultrasonic Sensor	12	2
R.M. Young 05305	15	31
Vaisala HMP155	12	2
Rotronic HC2-S3	15	2
CR 1000	14	3
CR 3000	1	2

5.2.5.1. Option 3a – Ultrasonic at Ground-Based Towers – Status-Quo Rooftop Towers

This approach sees the Ministry maintain its current maintenance routine at all roof-top locations, but replace existing meteorological instrumentation with an ultrasonic sensor and new Vaisala temperature and RH probe at ground-based locations. There is little case to be made to maintain stations to a quality standard that physical siting may render moot, so this option only provides different instrumentation at 10 m or higher ground-based towers. This also allows for redeployment of any CR1000 or Rotronic probes from sites with collocated EU dataloggers to other locations still requiring an update of aging instrumentation.

Option 3a requires just under $78,000 in capital and approximately $53,000 in operational funding, but reduces staff time from just less than 1100 hours to approximately 855 hours.

5.2.5.2. Option 3b

Option 3b follows option 3a, but further lowers maintenance costs by abandoning six-month checks on the R.M. Young 05305; there is no component replacement at these intervals, just a functional check. Following the rationale of 3a it may make the most sense to simply reduce effort at these sites, but still replace components at the previously accepted interval.

This option has the same capital costs as 3a but slightly lower operational costs, estimated to be approximately $47,500. Option 3b requires about 200 fewer staff hours, totaling approximately 515 hours, equivalent to just over $21,000 in wages and benefits.

5.2.5.3. Option 3c

Option 3c again mirrors 3a, and maintains the staff time requirements of 3b, but increases the investment in the R.M. Young 05305. This option would increase the sensor rebuild frequency to one year from two, but still not provide for scheduled six-month instrument checks. This would proactively replace instrument components, likely solving the high number of vane-torque failures outlined earlier, as well as any azimuth error. This comes with increased cost however, as required operational funds increase from $52,800 to about $70,500.

A summary of each costed option is provided in Table 16 – detailed cost estimates are available in Appendix E.

Table 16 - Options Cost Summary

	Status Quo	Option 1	Option 2	Option 3a	Option 3b	Option 3c
TOTAL CAPITAL	**$ 52,550**	**$ 52,550**	**$ 142,210**	**$ 77,613**	**$ 77,613**	**$ 77,613**
FTE ($)	$ 44,452	$ 88,905	$ 19,454	$ 35,111	$ 21,055	$ 21,097
Operational ($)	$ 52,570	$ 106,110	$ 53,421	$ 52,834	$ 47,654	$ 70,448
TOTAL OPERATIONAL	**$ 97,022**	**$ 195,015**	**$ 72,875**	**$ 87,954**	**$ 68,709**	**$ 91,545**
TOTAL	**$ 149,572.**	**$ 247,565**	**$ 215,086**	**$ 165,558**	**$ 146,322**	**$ 169,158**

6. Recommended Option

A decision matrix was established based on user feedback: the Ministry needs to ensure it meets its DQOs, but these should be applied to a more limited number of stations; cost control, and staff time are very important; and, the original objective of a standardised network is a tertiary objective.

The matrix was weighted for these attributes. All options required that they address meeting DQOs at sites with ground-based towers. This was a pass/fail component, so status quo was rejected.

Cost was scored out of a possible 45 points. The lowest cost option that meets the mandatory requirements is awarded 45 points, and each other cost is scored as a percentage of this (score = (lowest cost/cost) x 45) – this is a common approach in Request-for-Proposal submission evaluation. Staff time is scored similarly – the lowest total hours are awarded the maximum score, and all others are scored as a percentage following the same calculation. Cost did not include staff time to ensure it wasn't scored twice. Tables 17 and 18 present the staff time and scoring breakdowns for each of the above options.

Table 17 - Options Staff Time Requirements

Option	Status Quo	Option 1	Option 2	Option 3a	Option 3b	Option 3c
Time (h)	1082	2164	473	855	513	513

Table 18 - Options Analysis Scoring

Requirements	SQ	1	2	3a	3b	3c
Mandatory Requirements						
Addresses Data Quality	N	Y	Y	Y	Y	Y
Desirable Outcomes						
Cost (45)	-	35.5	28.8	43.2	45.0	38.1
Reduces Field Time (45)	-	9.8	45.0	24.9	41.5	41.5
Improves Standardization (10)	-	10	10	4	6	6
SCORE		55.3	83.8	72.1	**92.5**	85.6

Standardization was scored subjectively out of ten based on instrument types and maintenance requirements: a homogenous network would score ten points, an ad-hoc network would score zero. Options with fewer maintenance regimes will score higher than a similar network with fewer maintenance regimes. In this evaluation options one and two were scored highest as the network is standardized on a single technology. Option 3a scores lower, as it requires multiple instrument types, and maintains 12 and 24 month maintenance intervals on the R.M. Young 05305. Options 3b and 3c employ fewer maintenance requirements.

Based on this, **Option 3b** scores highest, and is the recommended path forward. Compared to current operations, the Ministry breaks even 58.6 months into the deployment, and solves data quality problems at all ground-based meteorological towers.

6.1. Discussion

Replacing sensors at some sites and streamlining data collection will help to improve data quality, save time and money for those conducting operations, and ensure that public funds are put to the best use.

This result may seem counter intuitive – the recommended path forward reduces maintenance at many sites and increases uncertainty with respect to data quality. This is true, but the same uncertainty exists for improving data quality: how good do roof-top monitors need to be? This project attempted to evaluate this, and siting seems problematic based on the large buildings some towers are mounted on such as schools and pulp mills. In the near-term this information can be used as screening criteria until a more robust network evaluation can take place. I suggest that this be a topic considered for a future network review, which is currently under discussion within the air program's leadership team.

It is entirely possible that individual meteorologists will demonstrate that some sites excluded from new instrumentation at this time warrant improved data quality, and request funding to do so. If so, the information contained within this report will provide useful guidance as to how this may be achieved.

7. Implementation Plan

Option 3b requires the replacement of instrumentation at twelve sites. To accomplish this, a phased implementation plan is provided below. This plan ensures that roles are consistent and clear, training is provided, available capital is expended by the end of fiscal year 2019, and that technicians are the lead for deployment scheduling and implementation. There's one limitation precluding more detailed planning: the position of unit head for the Air Monitoring group is vacant, so coordinated work-planning is premature, but the following will provide a solid framework that can be modified going forward. This is reflected in the work-plan breakdown below (Table 19) – timelines become less defined as they move further into the future, and outside of the role of ECMS.

Roles and responsibilities are as follows:

Knowledge Management Branch – Environmental and Climate Monitoring Section:

- Equipment procurement and distribution
- Training development and delivery
- Remote support
- Data validation and data standards.

Regional Operations Brach – Monitoring, Assessment and Stewardship:

- Acceptance of test data
- Deployment scheduling
- Instrument deployment and operation

The plan provides a stage-gate for decision making with respect to new technology: the sensors were tested on the south coast, so we have not assessed how well they operate in more severe conditions. As such, prior to the commitment of funds sensors will deployed in Kamloops over the winter, and if performance is unacceptable funding can shift to another option. If this happens the scoring and funding requirements above can be used to facilitate decision making.

Once the instruments are installed in Kamloops the data will be collected along with other parameters from this station. Existing validation processes will remain in place; however, through the test period ECMS's staff will review the data to determine whether new validation steps are required, and if the data generated pose any unique challenges such as if sensor icing occurs.

The recommended option requires just under $77,000 in capital; $40,000 has been earmarked for improvement to the meteorological network this fiscal year pending the outcome of this project, so investment can be split over two years. Stations such as Telkwa and Farmington should be delayed until the second year as the future of these sites is uncertain. Other sites can be selected once a new unit head is in place and work planning is underway in the next fiscal year, but a tentative plan is proposed below.

The twelve sites are to be upgraded are:

- Duncan
- Colwood
- Courtenay
- Squamish
- Merritt
- Cranbrook
- Grand Forks
- Williams Lake
- Farmington
- Smithers
- Terrace
- Telkwa

To build technician proficiency early the first sites should spread across as many regions as possible:

- **Year One:** Duncan (Vancouver Island), Squamish (Lower Mainland), Merritt (Thompson-Okanogan), Cranbrook (Kootenay), Williams Lake (Cariboo), Smithers (Skeena).
- **Year Two:** Colwood (Vancouver Island), Courtenay (Vancouver Island), Grand Forks (Kootenay), Terrace (Skeena); Farmington (Omineca-Peace) and Telkwa (Skeena) if required.

Training must happen prior to providing instrumentation to staff; however, the last annual training session took place in February. Assuming similar timing this fiscal year we will be unable to execute cold-weather testing and procurement prior to this. To mitigate this, training will be developed for remote delivery via Lync/Skype for Business, as well as accompanying documentation. This will include:

- Installation instructions that build on manufacturer's recommendations
- Logger configuration
- Verifying instrument operation

Deployments will likely take place in the spring and summer during good weather. All installations should take place during regularly scheduled maintenance to keep travel costs and staff time to a minimum, though an extra two hours of staff time has been added to each installation as a contingency. This can be reassessed after the Kamloops test installation.

The implementation plan is summarized in Table 19 below.

Table 19 - Implementation Plan

Task	Action	Staff	Budget	Notes
1: Sept 2018	Deploy to Kamloops for winter testing	Regional Technician (3 hours); Network Tech. Specialist (1 hour – remote support). ECMS systems/data staff (3 hours each)	None: to use internal mail system; have all required equipment	Already arranged with staff.
2: Jan 14, 2019	Verify acceptable performance	Regional Technician, Regional Meteorologist, Network Tech. Specialist, Technical Committee (2 hours each).	None	Meet to discuss data collected issues (if any), and resolutions. Make go/no-go decision.
3: Jan 21, 2109	Capital Procurement	Network Tech. Specialist (2 hours). Procurement Services.	$1,300 – procurement services charge (Province of British Columbia, 2018c).	Create requisition for sensors; $40,000 available if used before March 31. Suggest procurement split over two years: $38,800/y & procurement fees.
4: February 26, 2019	Develop Training Pan	Network Tech. Specialist (24 hours).	None.	Won't know specific model until bidding closes; once closed build training material and schedule delivery.
5: Mid- March	Delivery Training	Network Tech. Specialist; Technicians (2 hours each)	None – remote training via Lync.	Timing to be confirmed once new unit head in place.
6: Mid- March	Confirm stations deployment	Network Tech. Specialist; Monitoring Unit Head (1 hour each).	None.	Confirm list above with new unit head.
7: End March	Distribute equipment	Network Tech. Specialist (3 hours).	None. To be done via internal mail system.	
8: Spring/Summer 2019	Initial deployments	Regional Technicians (2 hours x 6), Network Tech. Specialist (6 hours).	6 x $41.07 x 2 = $492.84 time. (Province of British Columbia, 2018a);	To be completed during regular scheduled maintenance. Have added 2 hours staff time as contingency,

			$600 consumables.	and $100 per site for consumables (e.g., conduit). Lessons learned to be discussed during routine conference calls.
9: Fall 2019	Review initial data/deployments	Regional Technicians, Network Tech. Specialist; ECMS systems/data staff. (2 hours each)	None	Discuss data collected to date, deployments, lessons learned.
10: Winter 2019	Second round of capital procurement	Network Tech. Specialist (2 hours). Procurement Services.	$1,300 – procurement services charge (Province of British Columbia, 2018c).	$38,800 required.
11: Spring/Summer 2020	Second round of deployments	Regional Technicians 2 hours x 6), Network Tech. Specialist (2 hours).	6 x $41.07 x 2 = $492.84 time. (Province of British Columbia, 2018a); $600 consumables.	To be completed during regular scheduled maintenance. Have added 2 hours staff time as contingency, and $100 per site for consumables (e.g., conduit). Lessons learned to be discussed during routine conference calls.

Based on the information in Table 19 resource requirements are listed in Tables 20 and 21.

Table 20 - Implementation Plan Funding Requirements

Item	Cost	Notes
Capital	$77,613	Split over 2 years
Procurement Services	$2,600	Internal cost recovery
Total Capital	$80,213	
Consumables	$1,200	$100 per site
Total	$81,413	

Table 21 - Implementation Plan Staff Requirements

Staff	Time (h)	Notes
Air Network Technology Specialist	47	
ECMS Data and Systems Staff	12	Includes both staff
Regional Technicians	57	Includes seven technicians; largely contingency time
Regional Meteorologist	2	To confirm test deployment to Kamloops
MCS Monitoring Unit Head	1	To confirm deployment plan
Total	119	

8. Success Metrics

Ongoing evaluation of the implementation of this project, and the monitoring program in general will ensure that data quality is maintained.

Specific to this project several deliverables are established within the implementation plan – the Ministry should aim to:

1. Establish a test site in Kamloops by fall 2018.
2. Re-assess validation protocols using the test data through the early winter of 2018/19.

If the test is successful in Kamloops:

3. Expend available capital by the end of fiscal year 2019 on new sensing technology.
4. Develop training and deliver it to technicians in spring 2019.
5. Deploy sensors to six sites in 2019.
6. Deploy sensors to six sites in 2020.

Evaluation of the achievement of DQO's for the meteorological network should be ongoing and routine. It has not been accepted practice to use the as-found data from meteorological sensor assessments to invalidate observational data. It is possible to set a quality bar and simply reject data that are collected by instruments that do not meet it; this is routine with air quality gas or particulate analyzers. However, verification/calibration intervals are much less frequent with meteorological sensors, so large amounts of data could easily be discarded. Additionally, data use is varied, so data invalidated based on one use may be useful for another. A less conservative approach is to allow data users to make their own determination regarding data use, but to do so they will need access to useful meta-data. Notwithstanding the above:

7. Data standards should be established for individual stations based on the primary intended data use, and be realistically achievable based on siting and instrumentation limitations.

To determine how to best move forward a discussion took place with ECMS staff to explore and outline an approach. It was agreed that existing data validation process should continue, but that expanded annual reporting would allow for users to make their own assessment of data usability. There are limitations to this approach – external data users would only have this information if they request it, but public reporting may be explored as a mitigating strategy.

This reporting should include:

8. Data capture as a percent of total possible hours annually.
9. Calms periods - where wind speed is below 0.5 m/s - as a percent of total hours annually. An increase in calm periods may be indicating an increase in the starting threshold of the instrument. This may need to be increased to quarterly or monthly though normal variability may mean higher temporal resolution may not provide meaningful information.
10. Comparison of wind speeds to historical data using quantile-quantile plots. This will graph historical wind-speed percentiles against the current year to look for changes in the statistical distribution of data, indicating a systematic change in the data set.
11. Instrument maintenance – anecdotally data quality has been seen to improve this year over last year due to maintenance activities. Tracking maintenance with the above information will inform those operating stations whether their implemented maintenance routine is providing sufficiently high data quality.
12. Sensor performance check reporting – distributing the as-found state of sensors has not been routine, but should be done as a feedback mechanism to site operators. These should be summarized, as in section two, to characterize overall network performance.

13. Optionally, the Ministry may also choose to implement periodic CTS audits of stations to assess current instrument performance in-situ.

9. Conclusion

The Ministry has realistic, achievable DQO's for meteorological monitoring, but must ensure that station siting is clearly reflected in monitoring objectives and instrument selection. This project took a streamlined approach to station assessment, but future work should aim to take an in-depth approach to assess site locations, likely within the context of an external network review.

Ultrasonic sensors can provide a cost effective, lower-maintenance path forward to achieving better quality data, and will simplify the configuration of monitoring stations, but should be cold-weather tested prior to larger-scale deployment – this is achievable within the remainder of fiscal 2019.

Data validation and reporting procedures should undergo minor adaptation to ensure data users understand the quality of the data being generated, and that those charged with maintaining the network intervals can be fully informed by available information, like instrument or probe performance data.

Works Cited

Asserio, T. (2012). Product Planning and Marketing Implementation. TMGT 7114: Module 1 – Satisfying the Customer. Retrieved from https://learn.bcit.ca/d2l/le/content/247396/viewContent/1349071/View

BCMOE (2007). *Meteorological Sensors, Calibration and Routine Verification - Ambient Air Program Standard Operating Procedure*.

BCMOE. (2011, February 7). *CRMP - Data Standards Draft*.

B.C. Ministry of Environment [BCMOE]. (2013). *Meteorological Data and Sensing Requirements in the B.C. Ministry of Environment.*

BCMOE. (2015). British Columbia *Air Quality Dispersion Modelling Guideline.* Retrieved from http://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/bc-dispersion-modelling-guideline-2015.pdf

BCMOE. (2016). *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operator Version 2*. Retrieved from: https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/water_air_baseline_monitoring.pdf

Bettencourt, L & Ulwick, A. (2008). *Giving Customers a Fair Hearing.* MIT Sloan Management Review. Spring 2008, Vol. 49. No. 3. Retrieved from: https://learn.bcit.ca/d2l/le/content/247396/viewContent/1349074/View

Campbell Scientific (Canada) Corp. (2010). Instruction Manual – HMP45C Temperature and Humidity Probe. Retrieved from https://s.campbellsci.com/documents/ca/manuals/hmp45c_man.pdf

California Air Resources Board. (October, 2017). *2016 Annual Data Quality Report.* Retrieved from https://www.arb.ca.gov/aaqm/qa/dqreports/dqr16.pdf

Campbell Scientific (Canada) Corp. (2015). *Instruction Manual – 86000, 86106, 86004 Sonic Anemometers*. Retrieved from https://s.campbellsci.com/documents/ca/manuals/86000_man.pdf

Campbell Scientific Inc. (2017). Instruction Manual - HC2S3 Temperature and Relative Humidity Probe. Retrieved June30, 2017 from https://s.campbellsci.com/documents/ca/manuals/hc2-s3-l_man.pdf

Campbell Scientific Canada. (2018, a). 86004 [image]. Retrieved from https://www.campbellsci.ca/86004

Campbell Scienfic Canada. (2018, b). 05305-L Wind Monitor, Air Quality Version. Retreived from https://www.campbellsci.ca/05305-10-l

Googe (July 1, 2018). *USD to CAD.* Retrieved from https://www.google.ca/search?ei=ccw5W-74NNWT0PEPpZqd0A0&q=USD+to+cad&oq=USD+to+cad&gs_l=psy-ab.3..0i67k1j0l9.2455.2567.0.2993.2.2.0.0.0.0.57.113.2.2.0....0...1c.1.64.psy-ab..0.2.112...0i20i263k1j0i131k1.0.44_2USHMan4

Google Earth Pro (2018, a). Terrace Air Quality Station Site Location [Image]. Imagery Date September 1, 2013. Digital Globe. Elevation 4.14km.

Google Earth Pro (2018, b). Vernon Science Centre Urban Climate Zones [Image]. Imagery Date April 23, 2013. RDNO. Elevation 2.98km.

Google Earth Pro (2018, c). Vernon Science Centre Meteorological Tower Location [Image]. Imagery Date April 23, 2013. RDNO. Elevation 537m

Fox, T. (2013). *Memorandum: Use of ASOS meteorological data in AERMOD dispersion modeling.* Research Triangle Park, NC: United States Environmental Protection Agency. Office of Air Quality Planning and Standards. Retrieved from: https://www3.epa.gov/scram001/guidance/clarification/20130308_Met_Data_Clarification.pdf

Government of Alberta. (2016). *Air Monitoring Directive Chapter 7: Calibration.* Retrieved from: http://aep.alberta.ca/air/legislation-and-policy/air-monitoring-directive/documents/AMD-Chapter4-Monitoring-Jun26-2017B.pdf

Government of Alberta. (2017). *Air Monitoring Directive Chapter 4: Monitoring Requirements and Equipment Technical Specifications*. Retrieved from: http://aep.alberta.ca/air/legislation-and-policy/air-monitoring-directive/documents/AMD-Chapter4-Monitoring-Jun26-2017B.pdf

Gill Instruments Ltd. (2016). *Gill WindSonic M User Manual*. Retrieved from http://gillinstruments.com/data/manuals/1405-PS-0030%20issue%202%20WindSonic%20M%20Manual.pdf?iss=2.20170306

Gill Instruments. (2017). Gill WindSonic M [image]. Retrieved from http://gillinstruments.com/data/datasheets/WindSonicM-1405-0029-iss10%2003102017pdf.pdf

Met One Instruments Inc. (n.d.). Model 010C Wind Speed Sensors Operation Manual. Doc No. 010C-9800 Rev D.

Met One Instruments Inc. (2010). *010C Wind Speed Sensor 020C Wind Direction Sensor*. Grants Pass. Oregon.

Oke, T. (2006). *Instrument and Observing Methods Report No. 81 - Initial Guidance to Obtain Representative Meteorological Observations at Urban Sites.* World Meteorological Organization. Retrieved from: http://library.wmo.int/pmb_ged/wmo-td_1250.pdf

Province of British Columbia (n.d.). *Appendix 1 – Travel Allowances*. Retrieved from https://www2.gov.bc.ca/assets/gov/careers/all-employees/pay-and-benefits/appendix_1_travel_allowances.pdf

Province of British Columbia. (2018, a). *Salary Look-up Tool – Science Technical Officer*. Retrieved from https://www2.gov.bc.ca/gov/content/careers-myhr/all-employees/pay-benefits/salaries/salarylookuptool/bcgeu-jobs/sto?keyword=scientific&keyword=technical&keyword=officer&keyword=21

Province of British Columbia. (2018, b). *Travel Expenses*. Retrieved from https://www2.gov.bc.ca/gov/content/careers-myhr/all-employees/pay-benefits/expenses-allowances/travel

Province of British Columbia. (2018, c). *Procurement Services Fee Structure*. Retrieved from https://www2.gov.bc.ca/gov/content/governments/services-for-government/bc-bid-resources/support-services/procurement-services/psb-fee-structure

Province of British Columbia (2018, d). *Business Travel Accommodation Listing.* Retrieved from http://csa.pss.gov.bc.ca/businesstravel/Default.aspx

R. M. Young Company (n.d, a). *Instructions - Wind System Calibration - Recommended Calibration Interval, Procedure, and Test Equipment. Model 18860-90.* Retrieved from http://www.youngusa.com/Manuals/18860-90(B).pdf

R. M. Young Company (n.d., b). *Instructions - Wind Monitor-AQ Model 05305.* Retrieved from http://www.youngusa.com/Manuals/05305-90(V).pdf

R.M. Young Company. (n.d., c). *Instructions. Wind Monitor Model 05103.* Retrieved from http://www.youngusa.com/Manuals/05103-90(M).pdf

Texas Commission on Environmental Quality. (2017) *Annual Monitoring Network Plan 2017.* Retrieved from https://www.tceq.texas.gov/assets/public/compliance/monops/air/annual_review/historical/2017-AMNP.pdf

United States Environmental Protection Agency [USEPA]. (2000). *Meteorological Monitoring Guidance for Regulatory Modeling Applications.* Research Triangle Park, North Carolina. Office of Air Quality Planning and Standards. Retrieved from https://www3.epa.gov/ttn/scram/guidance/met/mmgrma.pdf

United States Environmental Protection Agency [USEPA]. (January, 2008). *Quality Assurance Handbook for Air Pollution Measurement Systems. Volume IV: Meteorological Measurements Version 2.0 (Final).* Research Triangle Park, NC: USEPA, Office of Air Quality Planning and Standards. Retrieved from: Retrieved from: https://www3.epa.gov/ttn/amtic/files/ambient/met/Volume_IV_Meteorological_Measurements.pdf

United States Environmental Protection Agency [USEPA]. (January, 2017). *Quality Assurance Handbook for Air Pollution Measurement Systems. Volume II Ambient Air Quality Monitoring Program.* Research Triangle Park, NC: USEPA, Office of Air Quality Planning and Standards. Retrieved from: Retrieved from:

https://www3.epa.gov/ttnamti1/files/ambient/pm25/qa/Final%20Handbook%20Document%20 1_17.pdf

Vaisala. (n.d.). Online Store. Retrieved from: https://store.vaisala.com/us/return-products-for-service/return-portal-services/WMT701/rdp#filterheader

Vaisala. (2014). Users Guide. *Vaisala WINDCAP© UIltrasonic WMT700*. Helsinki, Finland. Vaisala Oyj.

Vaisala. (2017). *Vaisala Wind Set WA 15 High Performance Wind Measurement.*

Vaisala. (2018). *Vaisala Wind Set WA15.* Retrieved from https://www.vaisala.com/en/products/instruments-sensors-and-other-measurement-devices/weather-stations-and-sensors/wa15

Vaisala. (2017) WINDCAP Ultrasonic Wind Sensor WMT700 Series [image]. Retrieved from https://www.vaisala.com/sites/default/files/documents/WMT700-Datasheet-B210917EN-J.pdf

Vaisala Oyj. (2002, a). *User's Guide Wind Vane WAV151.* Helsinki, Finland. Retrieved from https://www.vaisala.com/sites/default/files/documents/WAV151_User_Guide_in_English.pdf

Vaisala Oyj. (2002, b). *User's Guide Anemometer WAA151*. Helsinki, Finland. Retrieved from

https://www.vaisala.com/sites/default/files/documents/WAA151_User_Guide_in_English.pdf

Vaisala Oyj. (2013). *Humidity Conversion Formulas – Calculation formulas for humidity.* Retrieved from http://app.knowledge.vaisala.com/e/er?utm_campaign=&utm_medium=email&utm_source=Eloqua&utm_content=CEN-TIA-G-Humidity%20Conversion%20Formulas%20Autoresponder&s=1106&lid=2371&elq=58f7aa5758ec4c258e1fe2826c4d8339

Wiederick, R. (2017). *TMGT 8101 – Directed Studies – B.C. Air Quality Monitoring Program – Meteorological Monitoring Network Project Plan.*

Land Remediation Business Improvement Project

Project Update Presentation

November 14, 2018

Project Team

Core team

Kyle Murray
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Danielle Grbavac
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Lucy Hewlett
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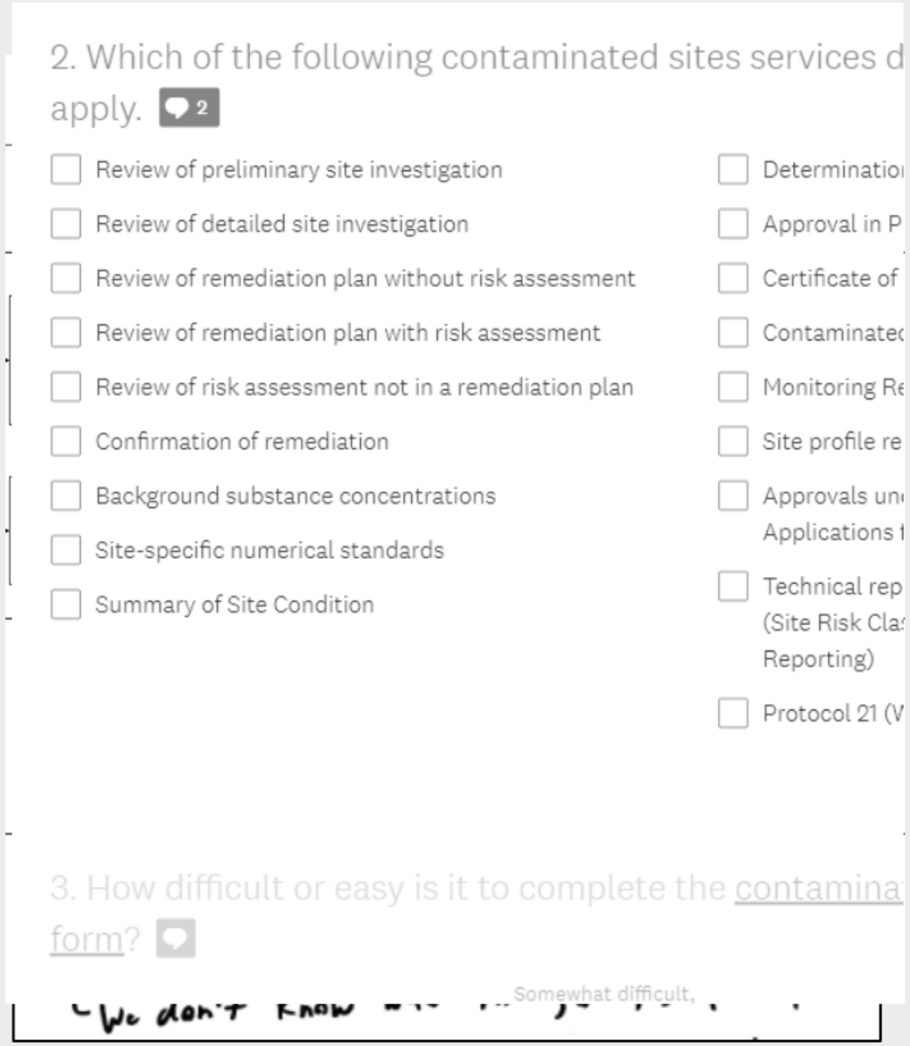
Vincent Hanemeyer



Summer 2017 – Staff survey

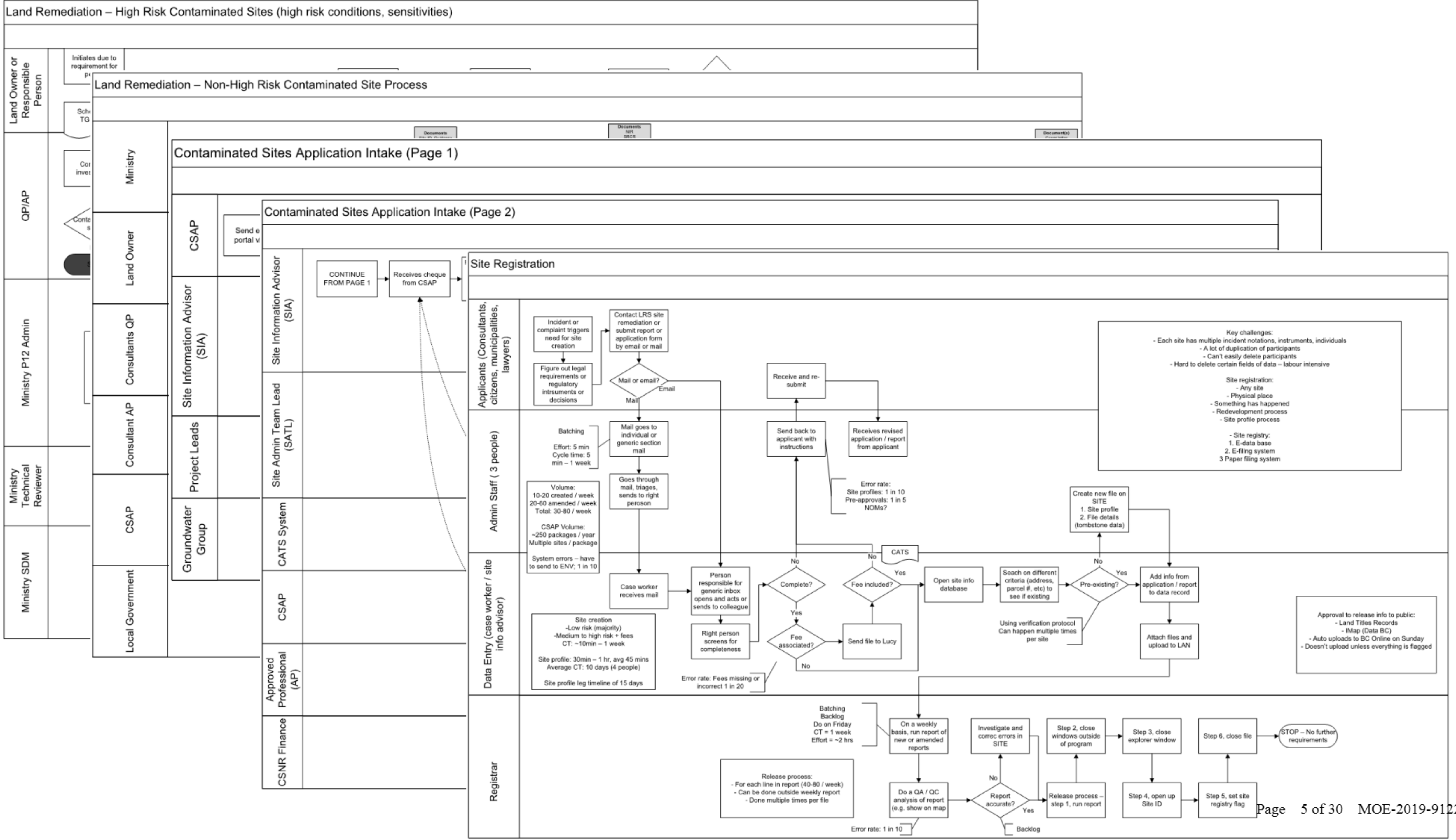
Fall 2017 – Focus groups

Winter/Spring 2018 – Process mapping

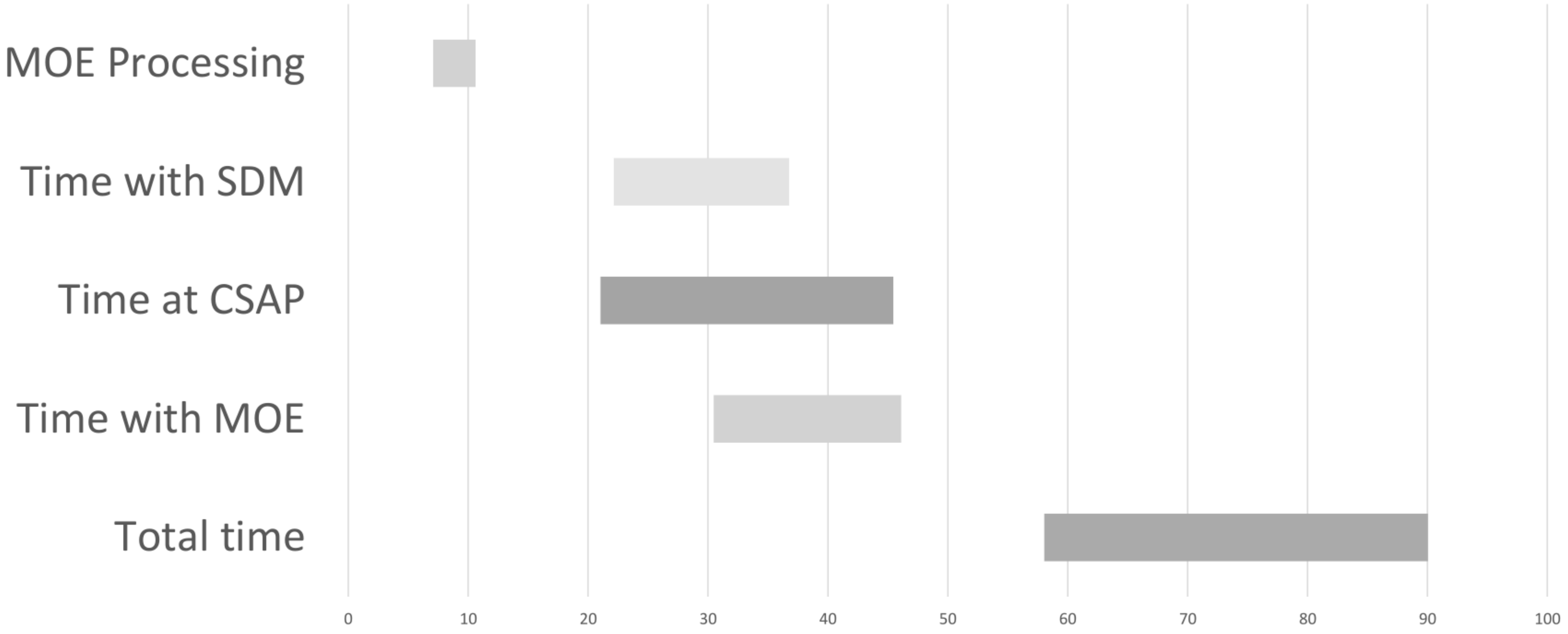
Client survey planning

Summer 2018 – Client survey + analysis

Process Mapping


Land Remediation – High Risk Contaminated Sites (high risk conditions, sensitivities)
Land Owner or Responsible Person
QP/AP
Ministry P12 Admin
Ministry Technical Reviewer
Ministry SDM
Initiates due to requirement for
Land Remediation – Non-High Risk Contaminated Site Process
Ministry
Land Owner
Consultants QP
Consultant AP
CSAP
Local Government
Documents
Contaminated Sites Application Intake (Page 1)
CSAP
Site Information Advisor (SIA)
Project Leads
Groundwater Group
Contaminated Sites Application Intake (Page 2)
Site Information Advisor (SIA)
Site Admin Team Lead (SATL)
CATS System
CSAP
Approved Professional (AP)
CSNR Finance
CONTINUE FROM PAGE 1
Receives cheque from CSAP
Site Registration
Applicants (Consultants, citizens, municipalities, lawyers)
Admin Staff (3 people)
Data Entry (case worker / site info advisor)
Registrar
Incident or complaint triggers need for site creation
Figure out legal requirements or regulatory intrsuments or decisions
Contact LRS site remediation or submit report or application form by email or mail
Mail or email?
Email
Mail
Mail goes to individual or generic section mail
Goes through mail, triages, sends to right peroson
Batching
Effort: 5 min
Cycle time: 5 min – 1 week
Volume:
10-20 created / week
20-60 amended / week
Total: 30-80 / week
CSAP Volume:
~250 packages / year
Multiple sites / package
System errors – have to send to ENV; 1 in 10
Case worker receives mail
Person responsible for generic inbox opens and acts or sends to colleague
Right person screens for completeness
Site creation
-Low risk (majority)
-Medium to high risk + fees
CT: ~10min – 1 week
Site profile: 30min – 1 hr, avg 45 mins
Average CT: 10 days (4 people)
Site profile leg timeline of 15 days
Error rate: Fees missing or incorrect 1 in 20
Receive and re-submit
Send back to applicant with instructions
Receives revised application / report from applicant
Error rate:
Site profiles: 1 in 10
Pre-approvals: 1 in 5
NOMs?
CATS
Complete?
No
Yes
Fee associated?
Send file to Lucy
Fee included?
Open site info database
Seach on different criteria (address, parcel #, etc) to see if existing
Pre-existing?
Using verification protocol
Can happen multiple times per site
Create new file on SITE
1. Site profile
2. File details (tombstone data)
Add info from application / report to data record
Attach files and upload to LAN
Key challenges:
- Each site has multiple incident notations, instruments, individuals
- A lot of duplication of participants
- Can't easily delete participants
- Hard to delete certain fields of data – labour intensive
Site registration:
- Any site
- Physical place
- Something has happened
- Redevelopment process
- Site profile process
- Site registry:
1. E-data base
2. E-filing system
3 Paper filing system
Approval to release info to public:
- Land Titles Records
- IMap (Data BC)
- Auto uploads to BC Online on Sunday
- Doesn't upload unless everything is flagged
Batching
Backlog
Do on Friday
CT = 1 week
Effort = ~2 hrs
On a weekly basis, run report of new or amended reports
Do a QA / QC analysis of report (e.g. show on map
Error rate: 1 in 10
Report accurate?
Investigate and correc errors in SITE
Backlog
Release process:
- For each line in report (40-80 / week)
- Can be done outside weekly report
- Done multiple times per file
Release process – step 1, run report
Step 2, close windows outside of program
Step 3, close explorer window
Step 4, open up Site ID
Step 5, set site registry flag
Step 6, close file
STOP – No further requirements

2017 Submissions, time to issue (95% C.I.)

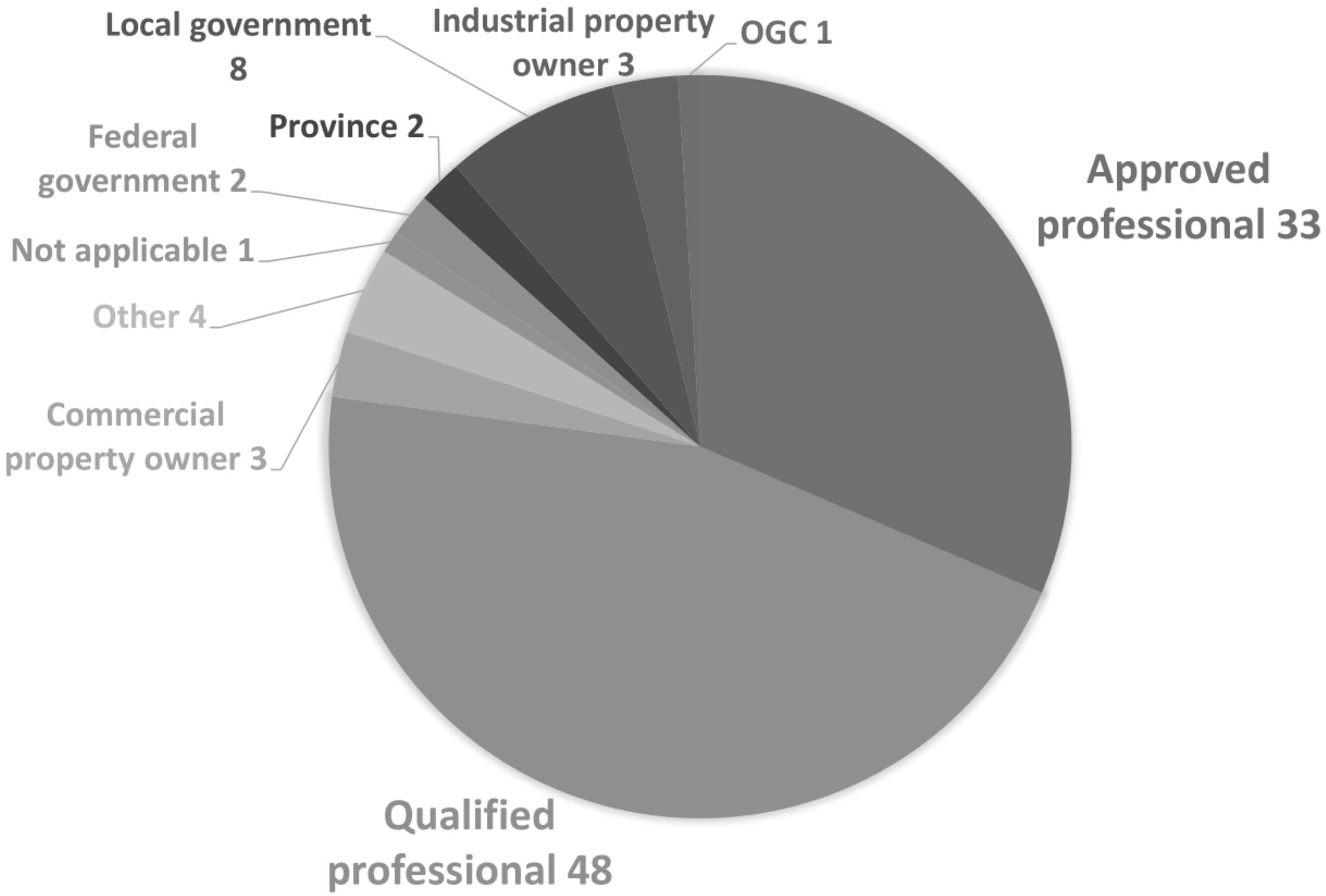


Client Survey

Client survey Quick facts

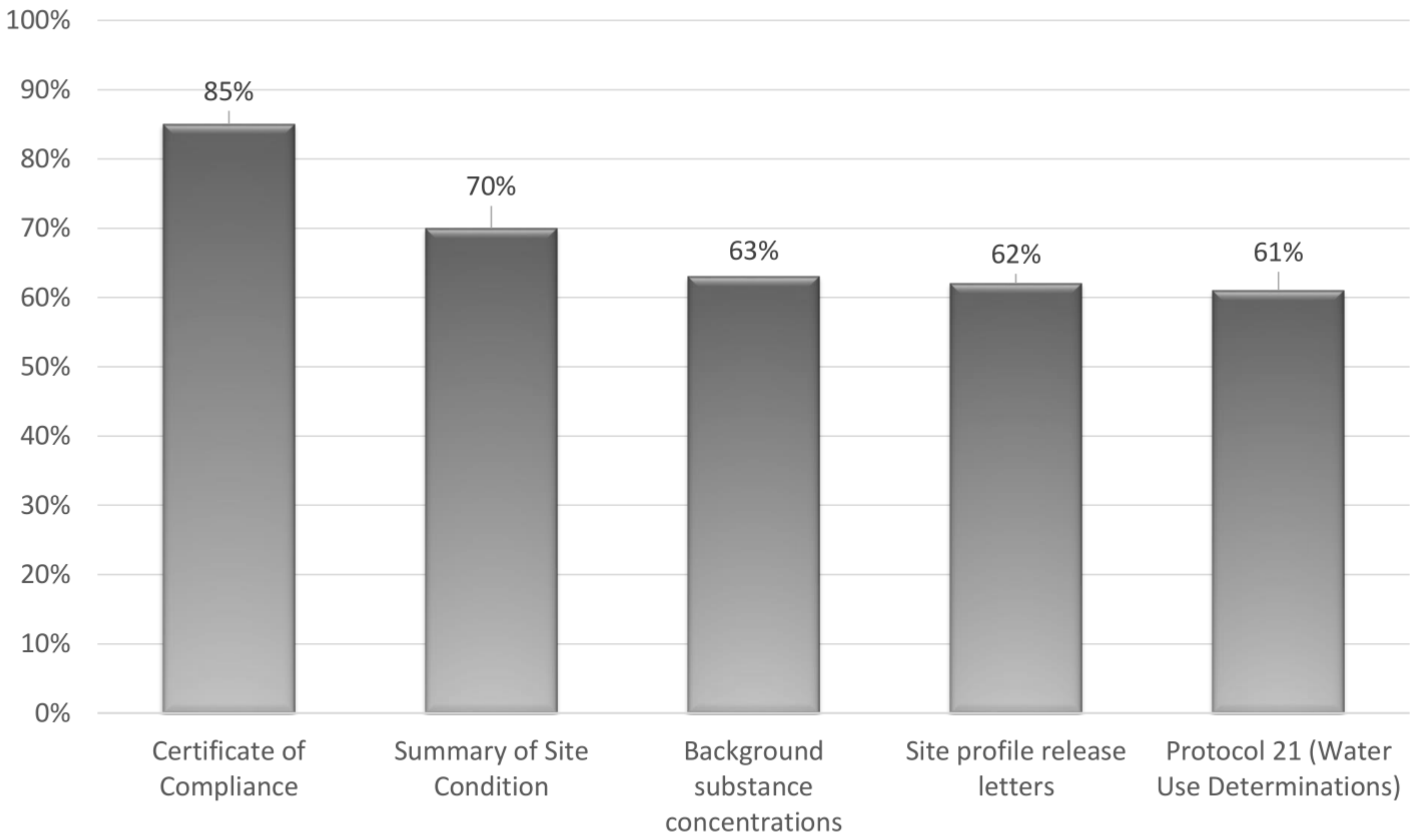
- Ran from July 20 to Sept 5, 2018
- 167 total repsonses
- 105 complete responses (63% completion rate)
- 81 responses from QPs / APs (77%)

In what capacity do you typically use Ministry of Environment and Climate Change Strategy advice and services for contaminated sites?

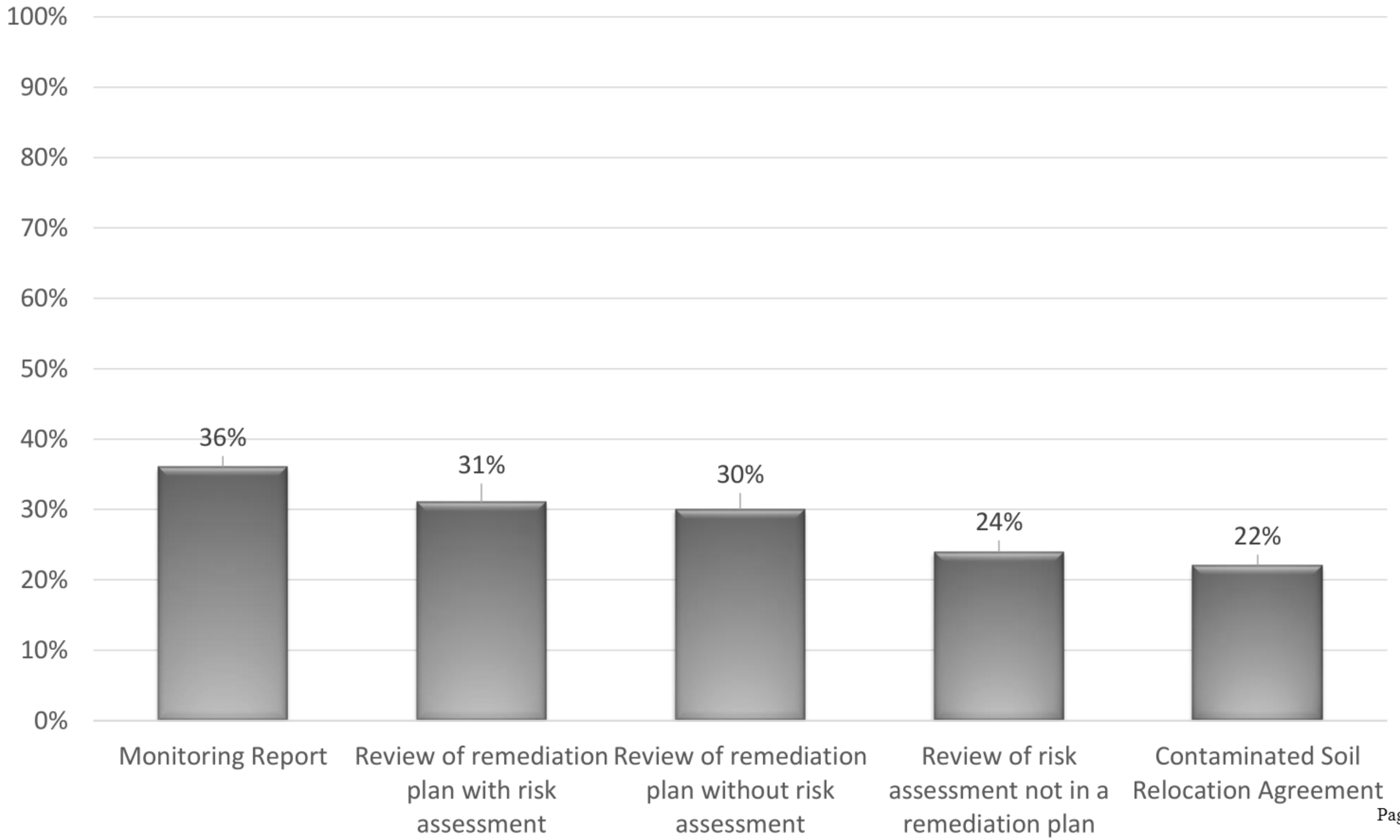


n=105

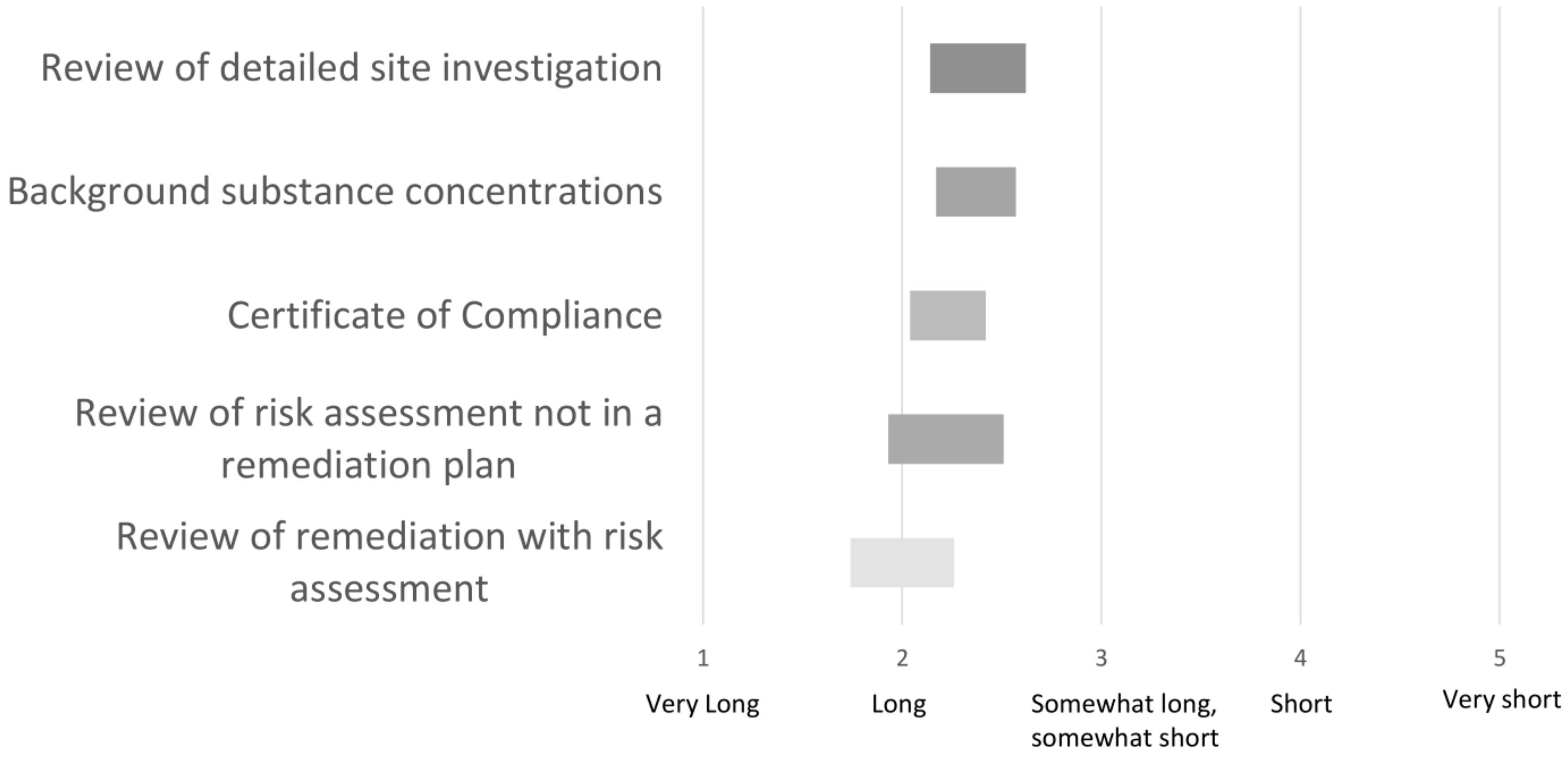
Top 5 services used



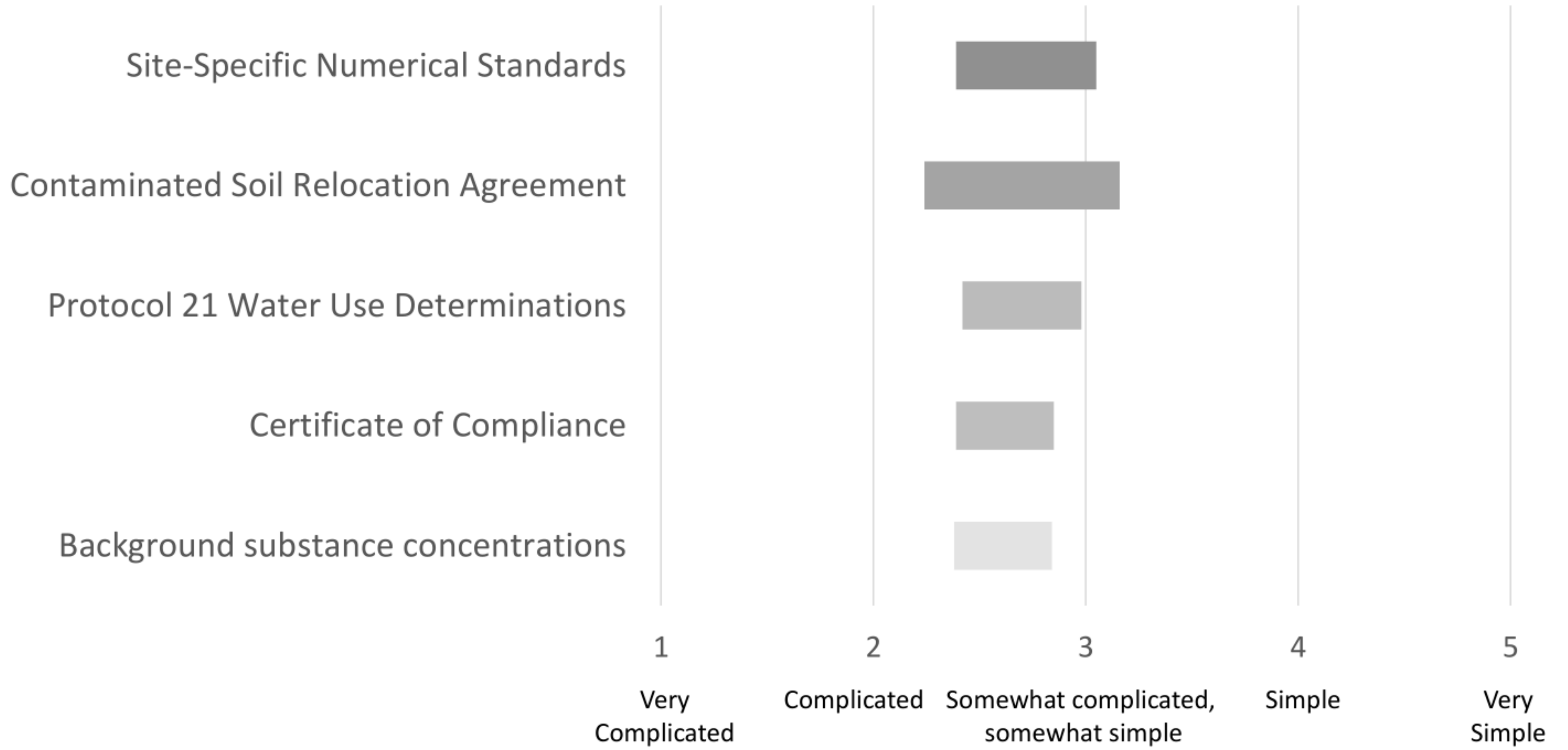
5 Least used services



Top 5 Longest Times to Receive Services (95% CI)



Top 5 Most Complicated Processes to Obtain Services (95% CI)



How do you rate the professionalism of the Ministry staff who respond to your requests? (95% C.I.)

Open ended responses by category

Forms	23.29%	17
Guidance	21.92%	16
Policy	28.77%	21
Positive Feedback	2.74%	2
Process	6.85%	5
Professional Reliance	19.18%	14
Staff	16.44%	12
Wait times	27.40%	20
Untagged	4.11%	3

Text responses: Forms

- “All forms in one place”
- “Fillable PDFs”
- “Clearer application”
- “Improve the process by streamlining and simplifying all the forms”
- “Have an intelligent online form”
- “Fillable forms”
- “All forms… electronically fillable”
- “Online forms”
- “Eliminate… multiple paper copies… and go totally electronic”

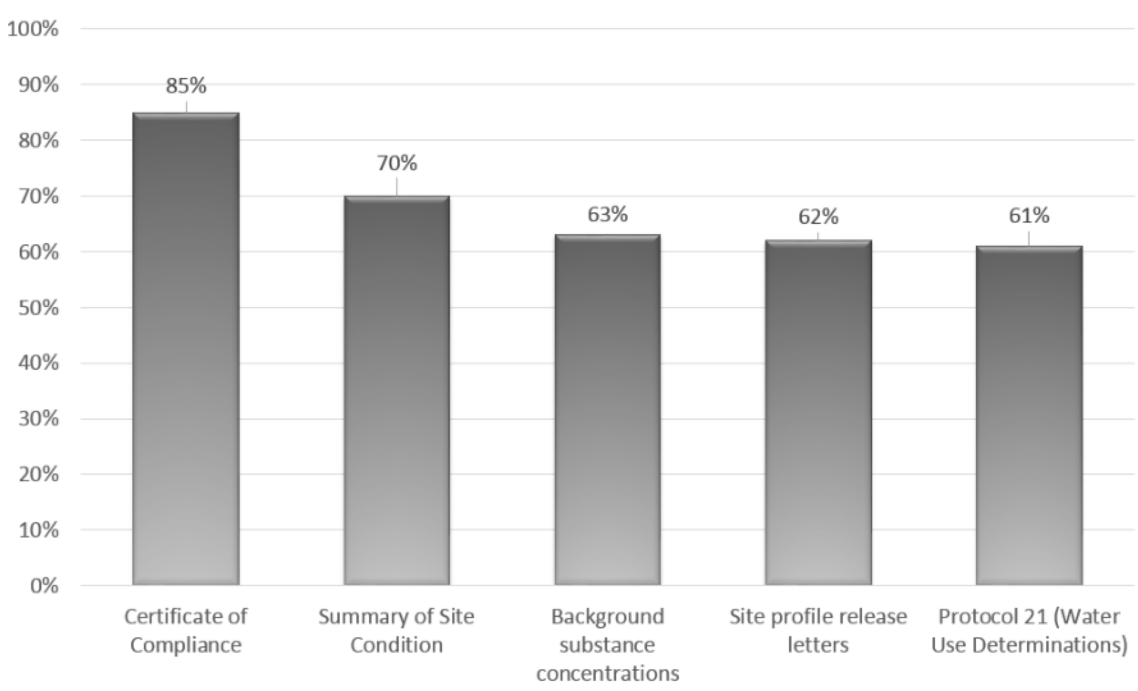
Text responses: Wait times

- “Clearer indication of turnaround times”
- “More BC MOE staff to shorten turnaround times”
- “Timely responses to email/phone calls”
- “Improve on ENV call back time”
- “Speed up processing of instruments and approvals”
- “Faster processing times for legal instruments”
- “Response and approval times… have been extremely long”
- “There should be a specified review time frame”
- “Staff sometimes too busy to respond in timeframe needed”
- “Improve timelines to process documents”
- “Alleviate backlog of ENV reviews”
- “The biggest issue… is the time it takes… [for] their specific approval”

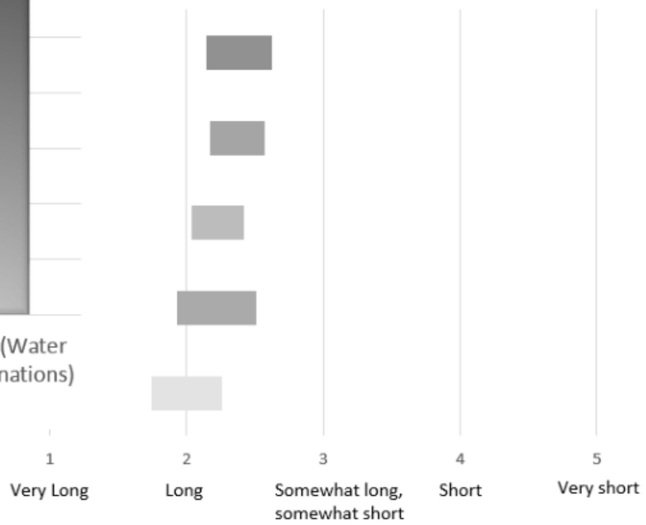
Text responses: Staff

- “More BC MOE staff to shorten turnaround times”
- “More MOE staff to support”
- “More responsiveness from ministry staff”
- “Staff sometimes too busy to respond in time frame needed”
- “The Ministry seems chronically understaffed”
- “Hire more Land Remediation staff. They are awesome.”
- “More MOE staff.”
- “More Ministry staff to shorten instrument waiting times”
- “Increase staffing to reduce response times”
- “Having a larger staff… so the review process is not as long”

Top 5 services used



ceive Services (95% CI)



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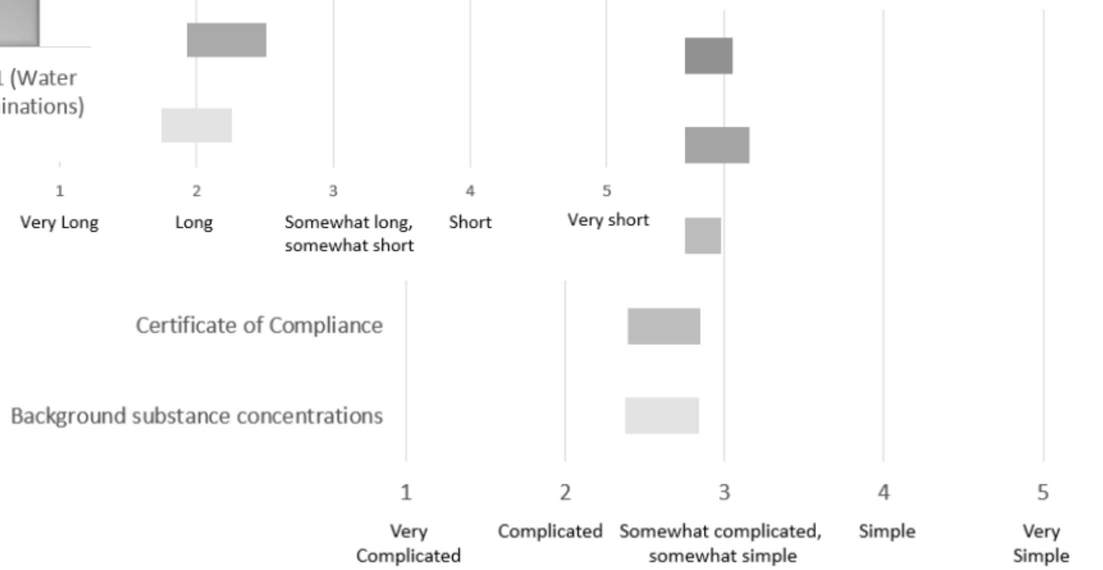
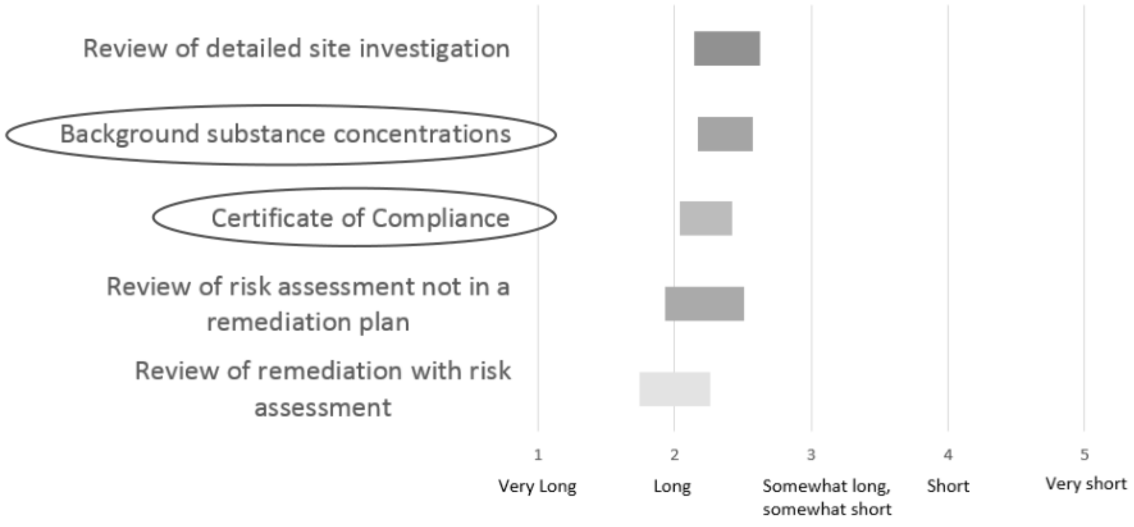
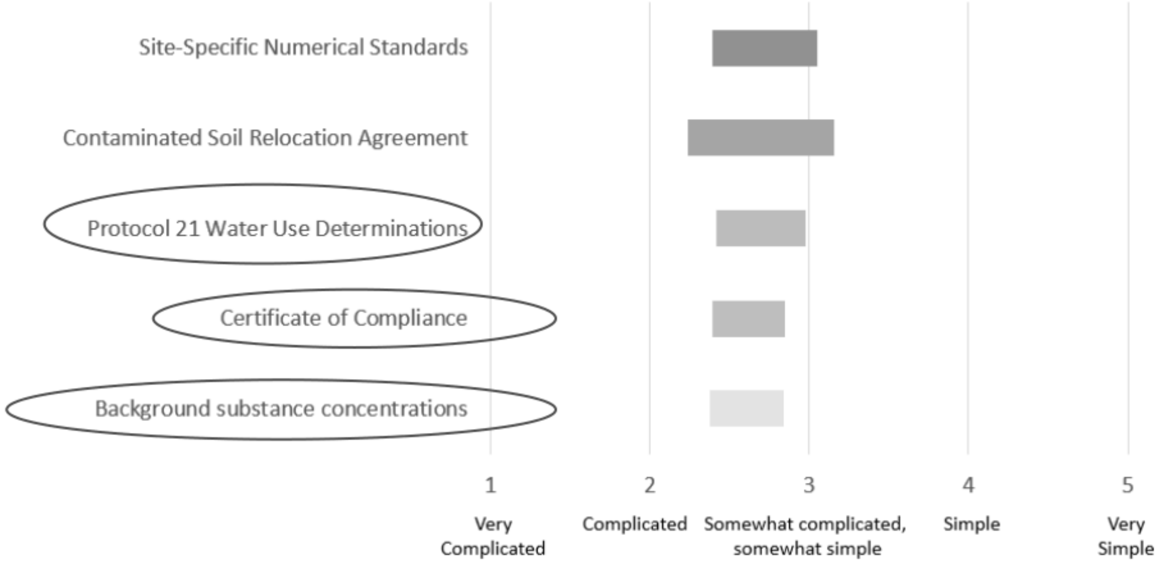


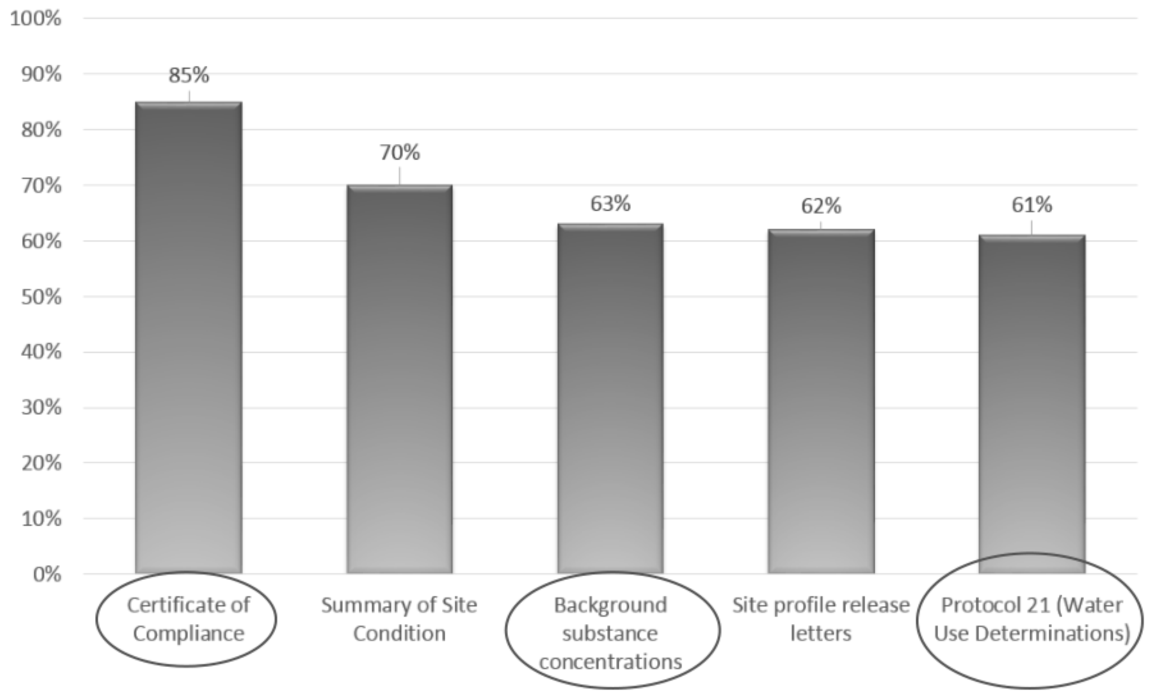
Top 5 Longest Times to Receive Services (95% CI)



Top 5 Most Complicated Processes to Obtain Services (95% CI)



Top 5 services used



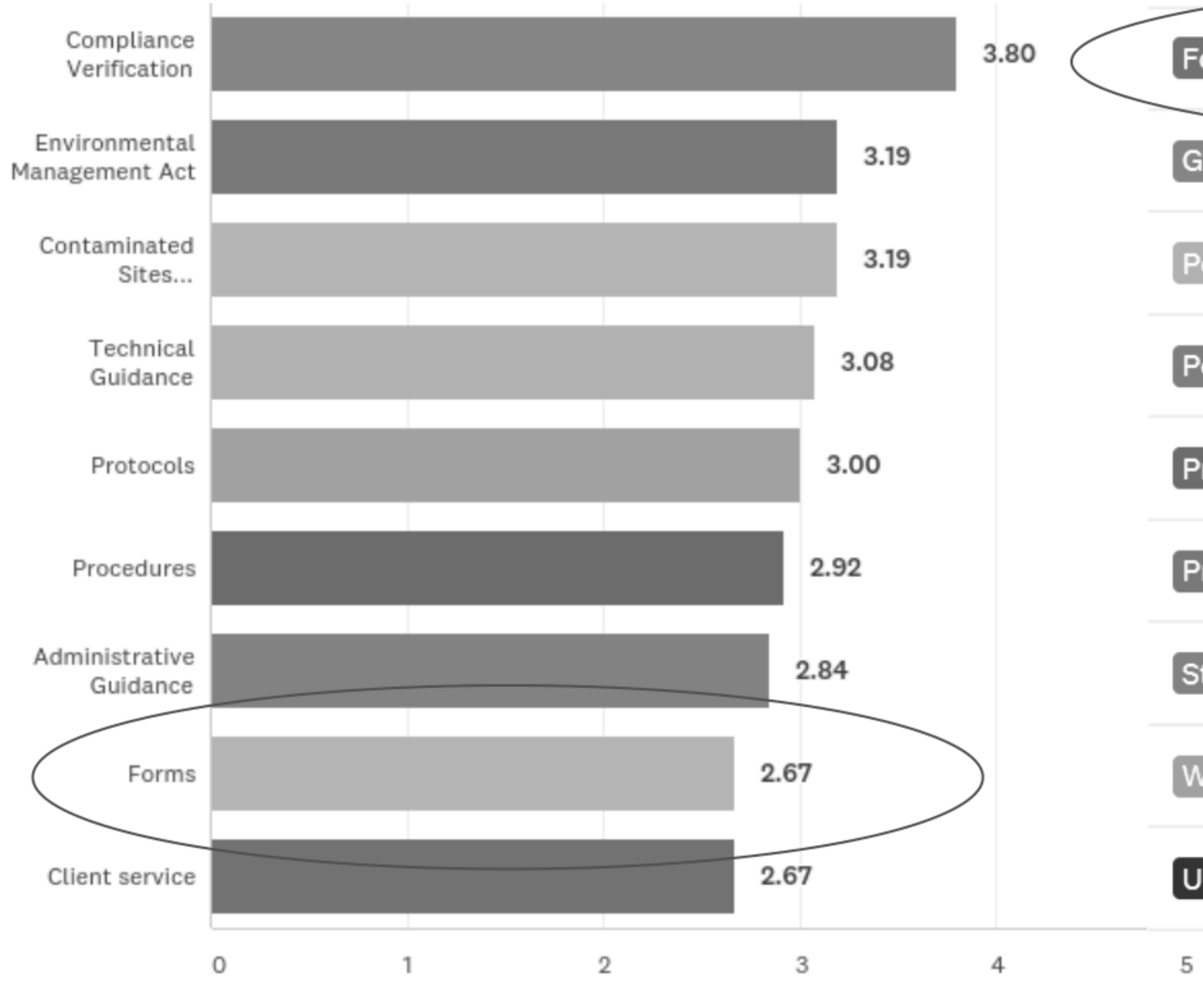
Insights from text analysis

- Wait times consistently cited
  - Clients tend to blame forms or staff shortages
    - Submissions spend just as long with CSAP as with MOE!

- QPs/APs *do* want improved forms

- Few consistent themes on policies or statutory regime

Comparison to staff survey



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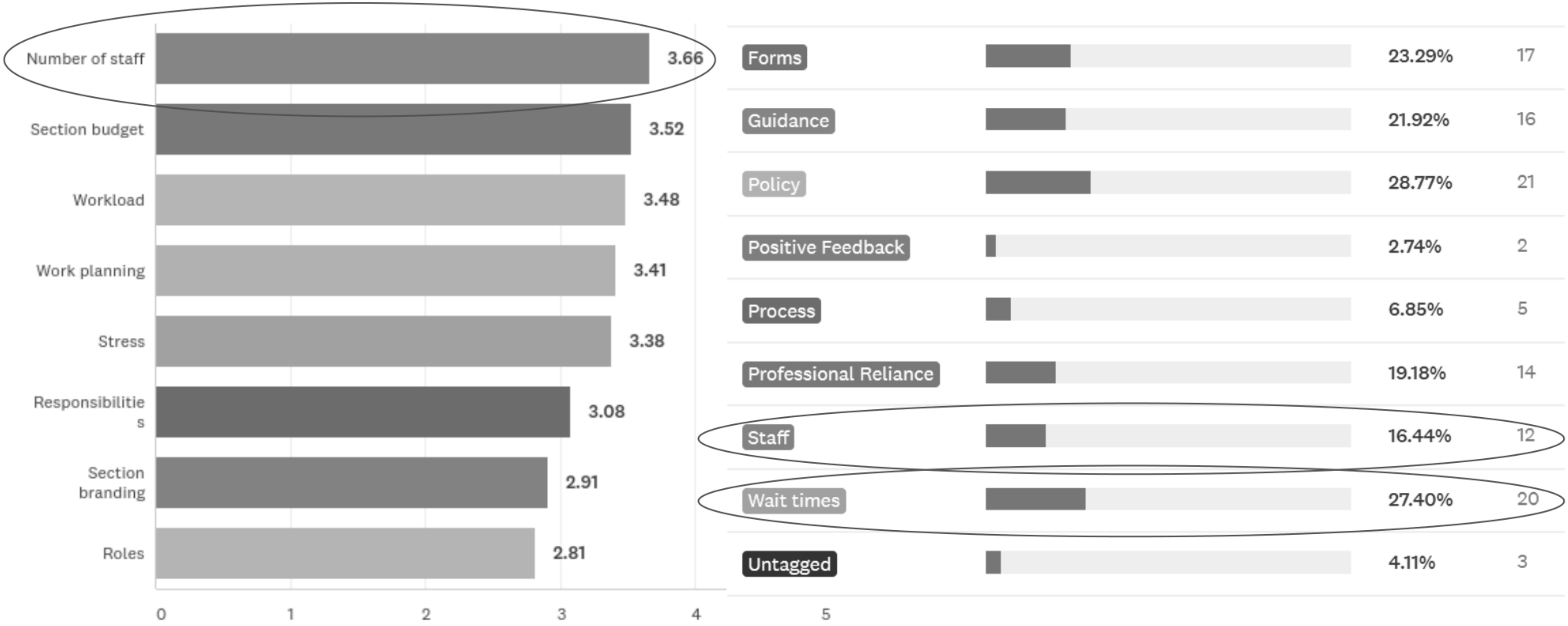
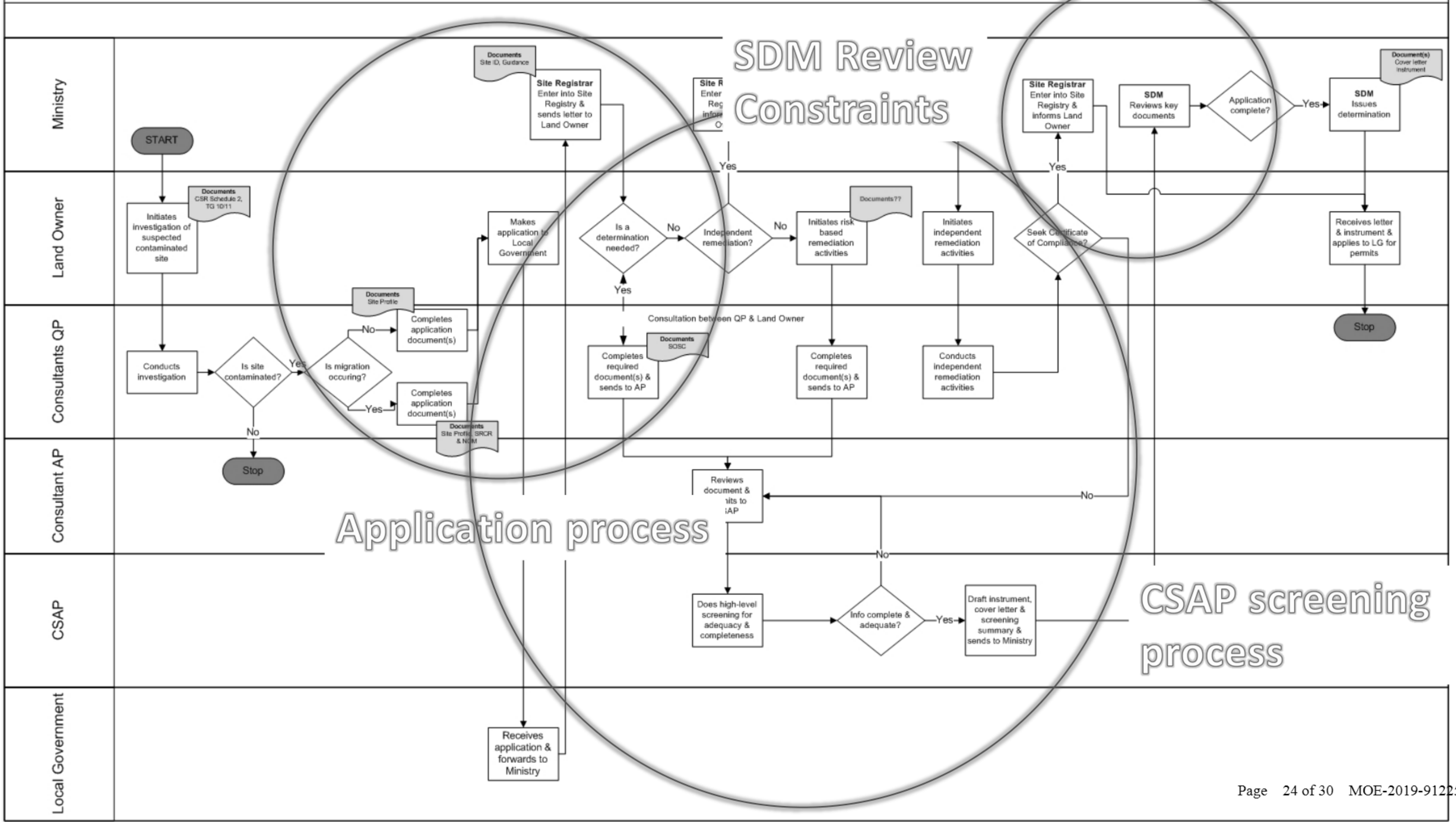
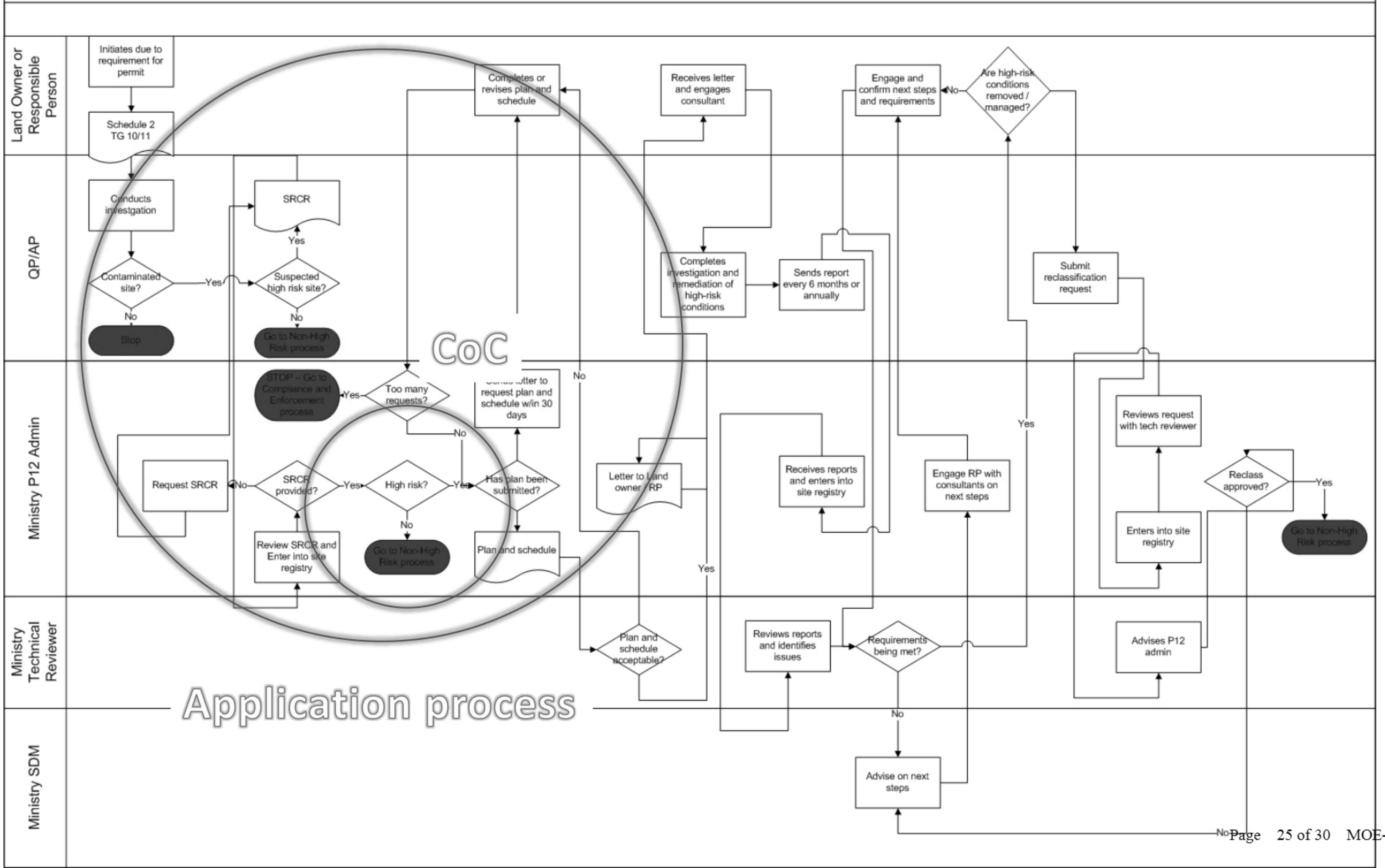
Comparison to staff survey



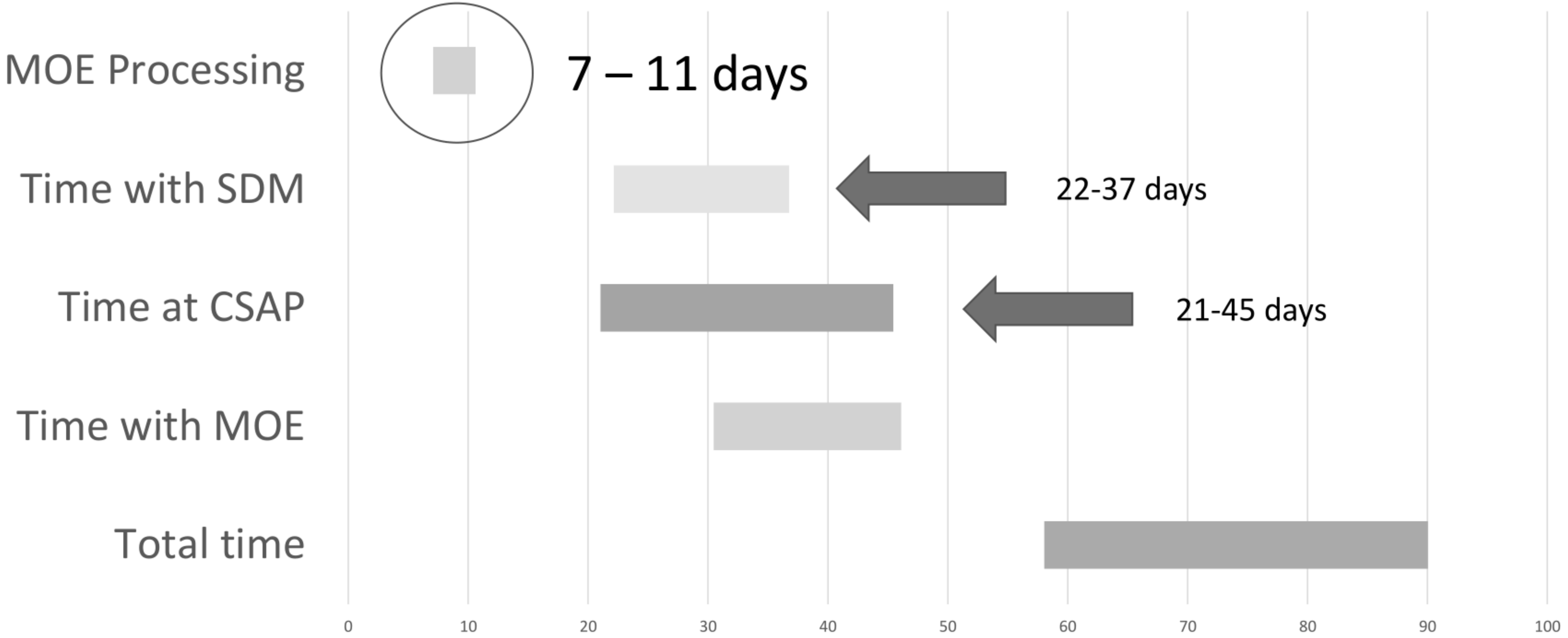
Land Remediation – Non-High Risk Contaminated Site Process



Land Remediation – High Risk Contaminated Sites (high risk conditions, sensitivities)



2017 Submissions, time to issue (95% C.I.)



Recommendations

1. Improvement workshop for application processing

2. Move to an online application & payments system
    - Eliminate unnecessary manual steps
    - Reduce errors, back & forth, stale dated cheques
    - Improve record keeping, analytics and reporting
    - Reduce burden on both clients and staff
    - Time and cost savings for both CSAP and MoE

Recommendations

3. Review CSAP screening process
   - Better understand their process
   - Is there a bottleneck?

4. Investigate opportunities to improve review process internally
   - SDM review time biggest opportunity
   - Explore Kanban approach for delegating work

Recommendations

Questions

?