BC Hydro Strategy for Replacement of Equipment

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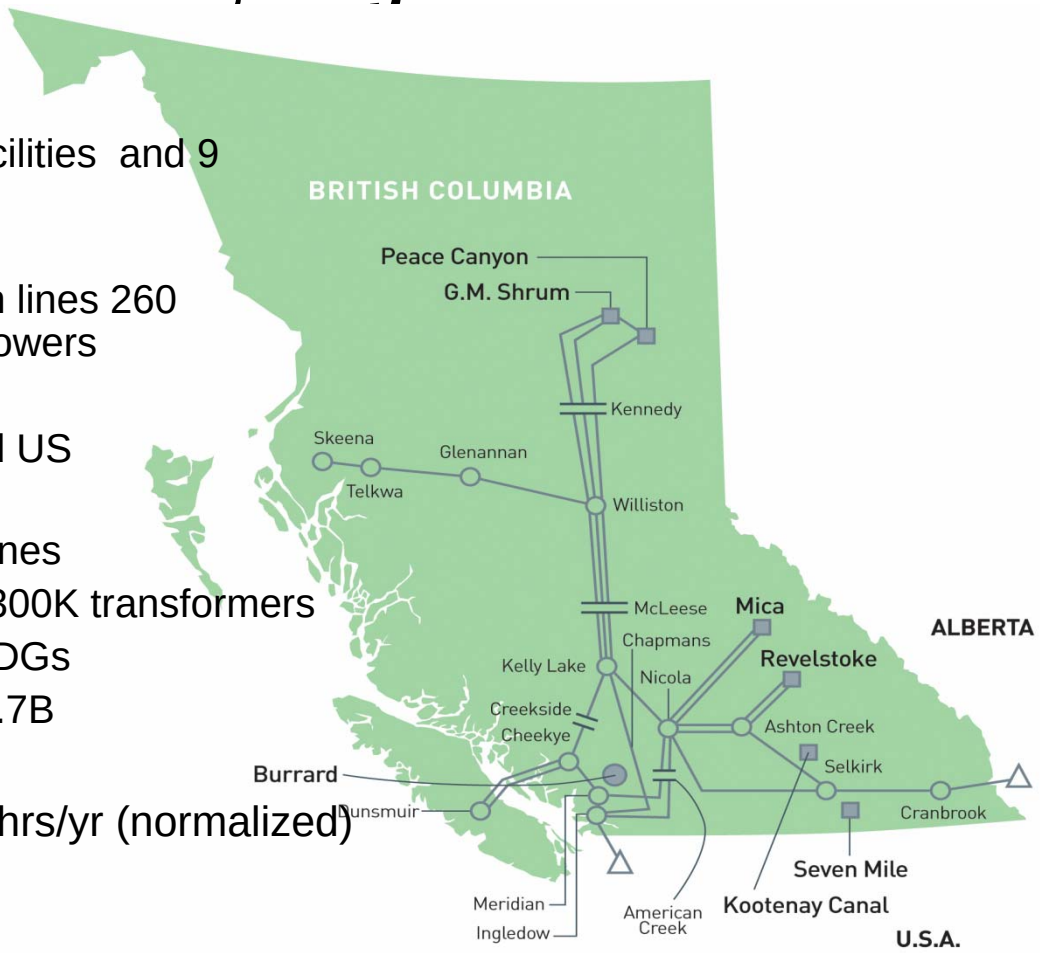
The BC Hydro System
– Reliable Power, at low cost, for generations

- **Generation**
  - 41 Dam sites, 30 Hydro facilities and 9 Thermal units
- **Transmission**
  - 18,000 km of Transmission lines 260 substations, 22,000 steel towers
  - Two Control Centers
  - Interconnect to Alberta and US
- **Distribution**
  - 56,000 km of Distribution lines
  - Approx. 900K poles, over 300K transformers
  - Non-integrated areas and DGs
  - Replacement Cost CAD$5.7B
- COMA/Customer ~US$120
- SAIDI = 5.2 hrs/yr (total); 4.1 hrs/yr (normalized)



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The Challenge

- *Provide an empirical evaluation of distribution system "health", to gauge the effectiveness of asset maintenance and replacement investments.*
  - *Age is not an effective measure of "health"*
  - *System composed of many components of differing "value" (quantity, cost, impact on performance)*
  - *Definition of failure – functional versus conditional*
  - *Repair versus Replace, O&M versus Capital*

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Asset Health?

- On a scale of 1 to 10 how “healthy” is your transportation asset (car)?

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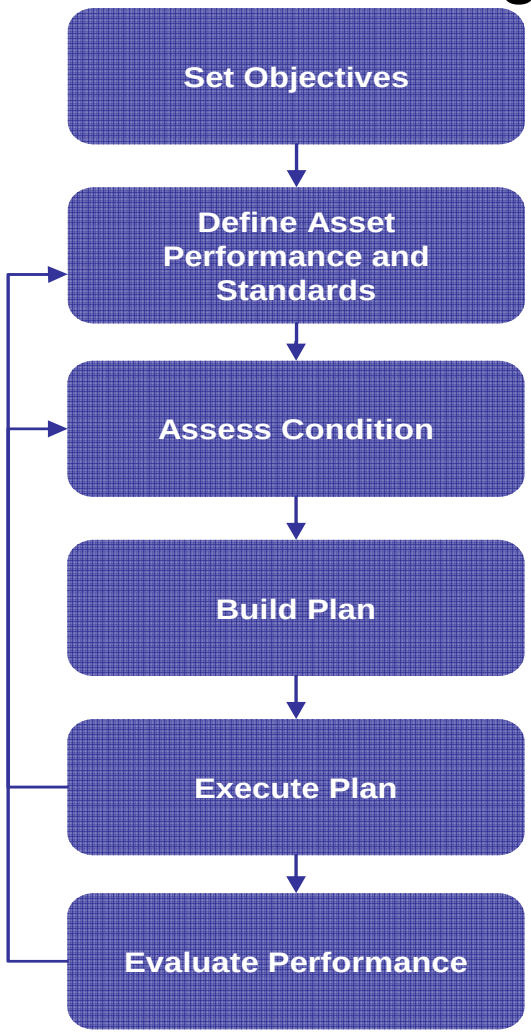
Distribution Maintenance – Planning



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Set Objectives

There are two primary objectives of planning for maintenance and replacement capital:

- Ensuring that performance requirements are defined and met, both now and into the future
- Costs are minimized over the asset life-cycle.

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Define Asset Performance and Standards

DM plans for maintenance and capital replacement programs from the ‘bottom-up’, based on the ability of each asset to meet its intended purpose. These purposes include:

1. Protecting workers and the public from electrical and other hazards;
2. Maintaining system capabilities such as delivering energy and lighting streets; and
3. Protecting equipment from catastrophic damage.

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Maintenance and Condition Assessment Programs

Distribution Maintenance
Work Planning Guidelines

Category	Activity	Cycle Time
O/H Public Safety	Inspecton	Annual
O/H Infrared Thermography	Inspecton	Urban(4 Yrs),Mixed(5 Yrs),Rural (DMPO)
O/H Air Break Disconnects	• Visual inspection • Infrequent operaton, operate, lubricate • Service and maintain (all)	• Each time operated • 2 years • 7 years
Reclosers	• Oil, initial maintenance • Vacuum, initial maintenance • Electronic, initial maintenance • Subsequentcycle	• 3 years or 200 ops • 5 years • 3 years, 1 year battery • Max. 5 years or 300 ops
Capacitors	• Visual inspection • Oil switch, change oil • Vacuum switch	• Annual • 5 years or 3,000 ops • none
Step Voltage Regulators	• Inspecton & operaton • Oil sample, initial • Subsequentoil sample • internal inspecton	• Annual • 1 year • 50,000 operaitons • 100,000 operaitons
Equipment Control Devices	• Inspecton/Battery Changes	• 5 years
Poles	• FLT Cedar initial inspection • FLT Non-Cedar initial inspecton • BT initial inspection • UT & HT in itial inspection • All subsequentinspectons	• 20-27 years • 14-21 years • 14-21 years • 8-15 years • 8 years
Street Lights	• Group relamping	• 4 years
URD, UD Public Safety	Inspecton	Annual
Live Front Interior	Inspecton	2 years
Dead Frontinterior	Inspecton	8 years
Vault and Padmount Thermography	• Thermography network vaults, dual radial street vaults, building vaults • Thermography switchgear and transformers • Thermography switching kiosks, SICs	• Annual • Whenever padmount or vault opened • Before switching done
Network Transformers and Street Vaults	• Cleaning • Visual • Network protector functional test • Oil dielectric test • Transformer electrical tests • Network protector internal inspecton and calbration • Switch compartment internal inspection and oil change • Cleaning and lubrication of SIC's • Transformer oil sample for lab analysis	• Annual • Annual • Annual • Annual • 5 years • 5 years • 5 years • 5 years • 5 years
Building Vaults with Hydro Equipment	Visualinspecton	Annual

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Asset Condition

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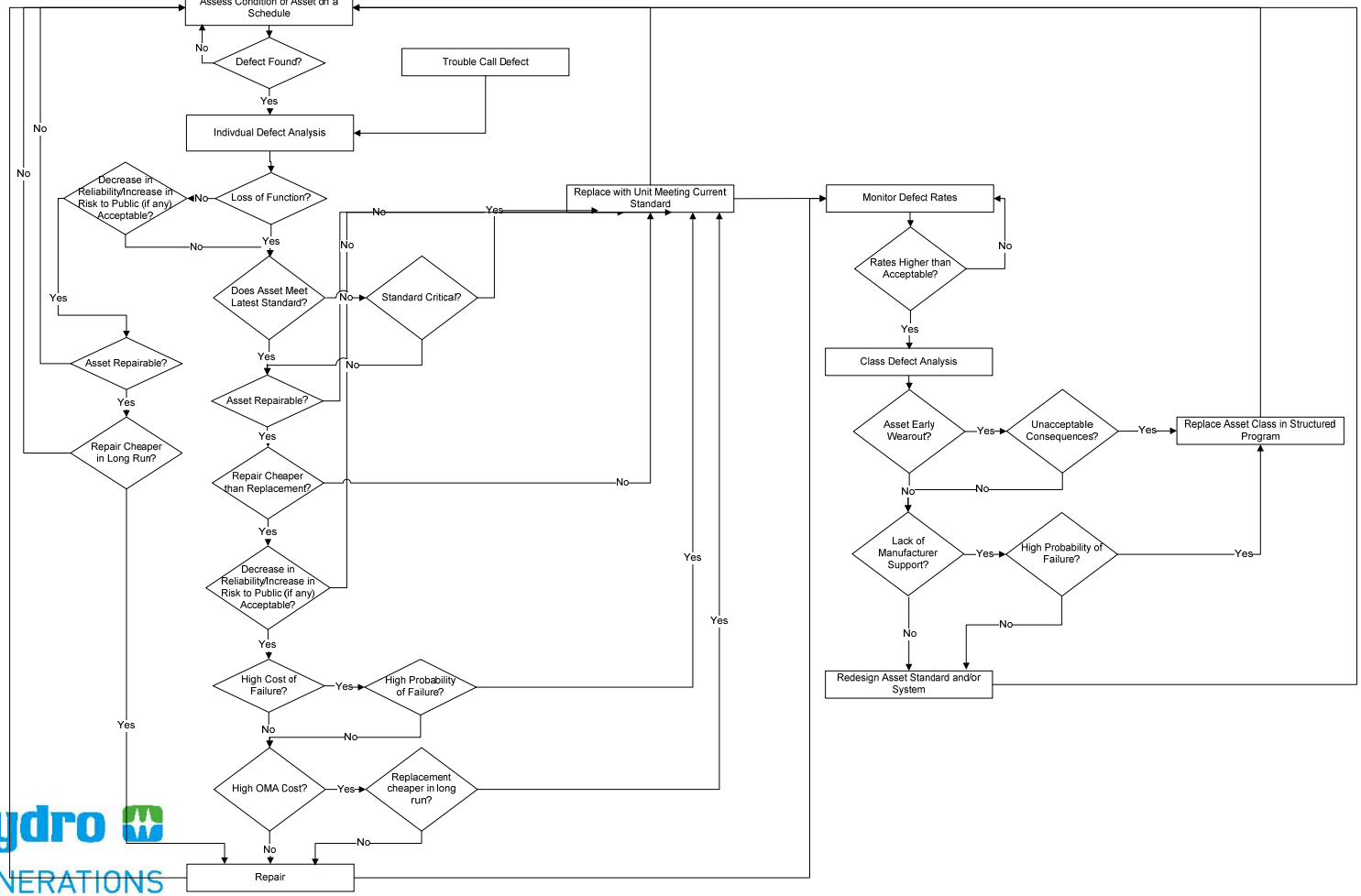
Asset Condition Assessment



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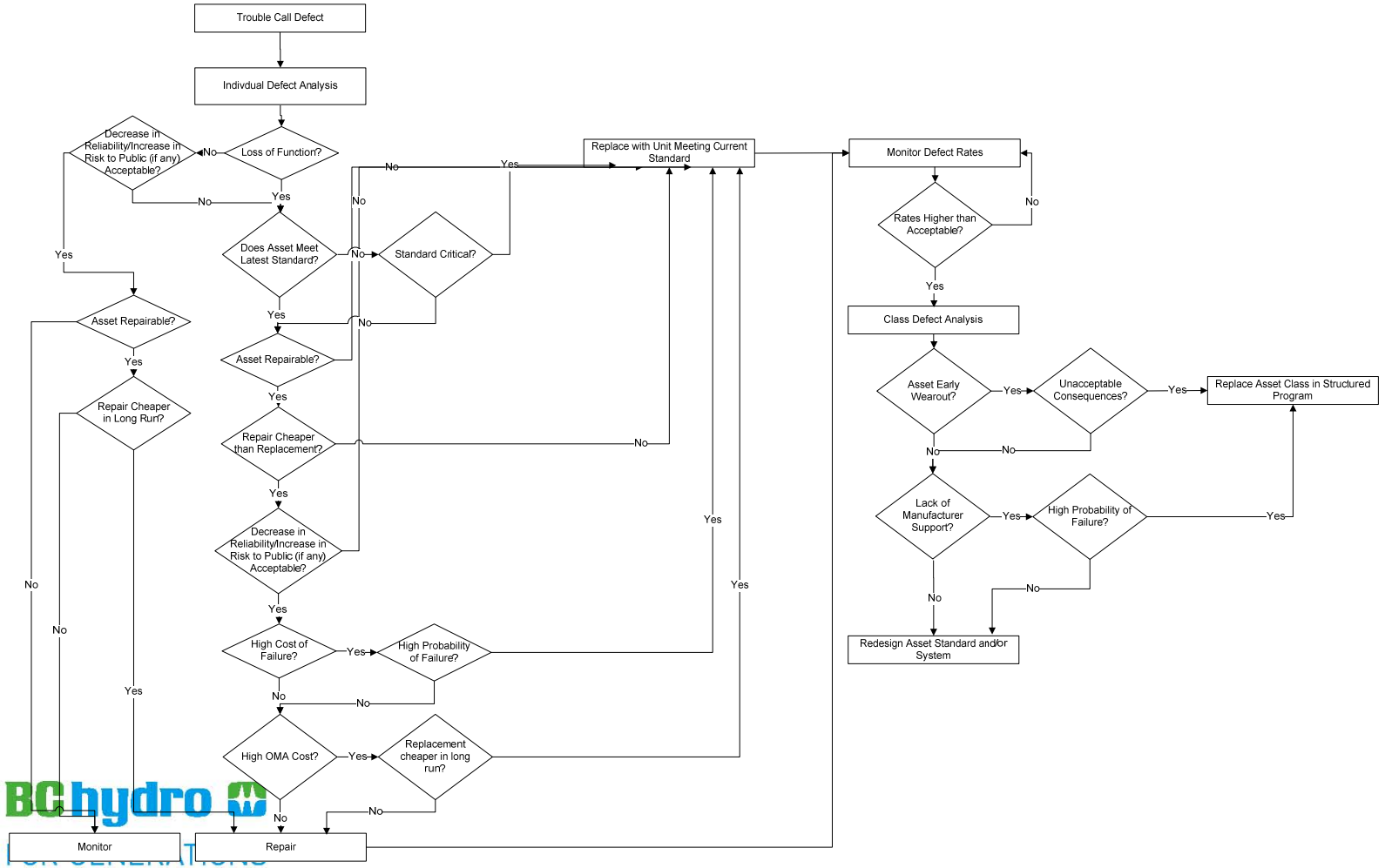
Perform Below Ground Inspection

Run to Failure



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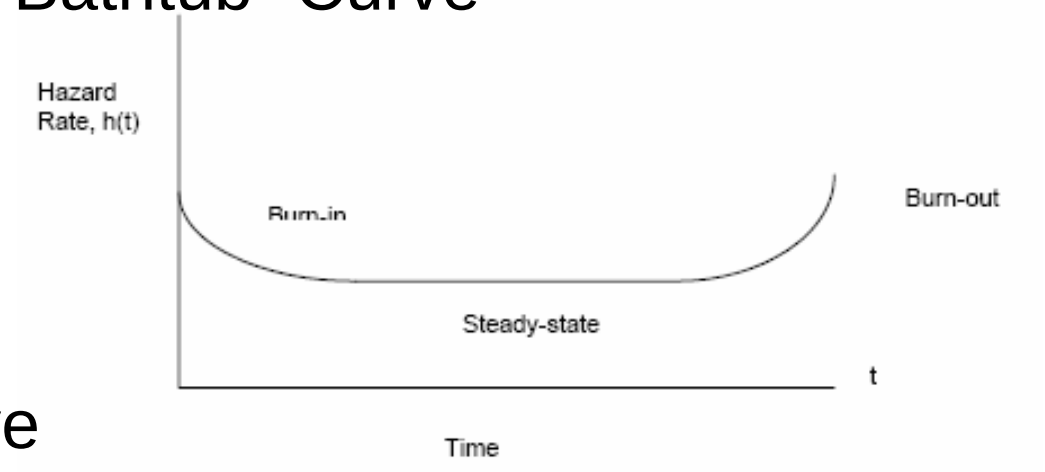
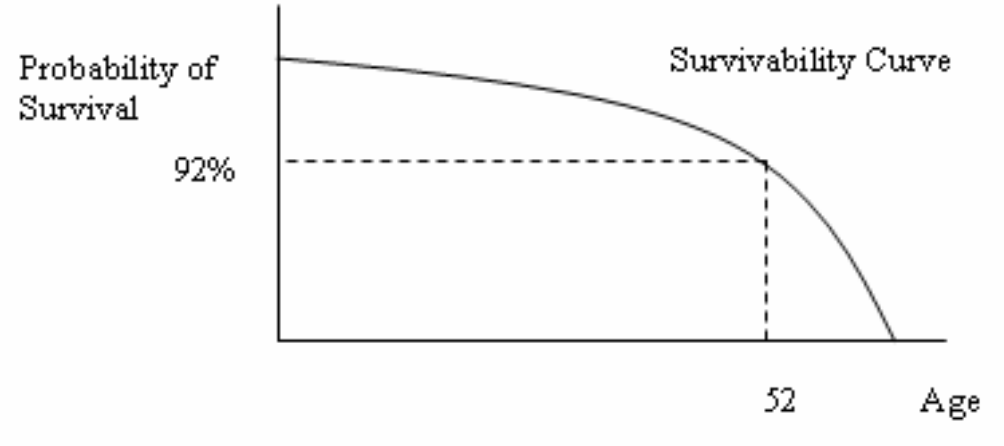
Perform Below Ground Inspection

Traditional component failure models

- Hazard Rate “Bathtub” Curve



- Survivor Curve



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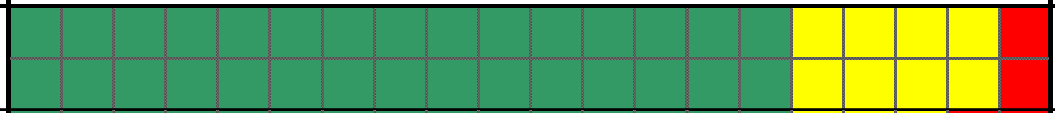
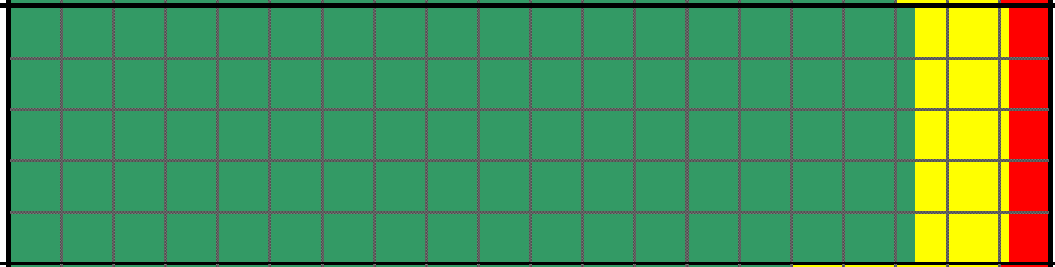
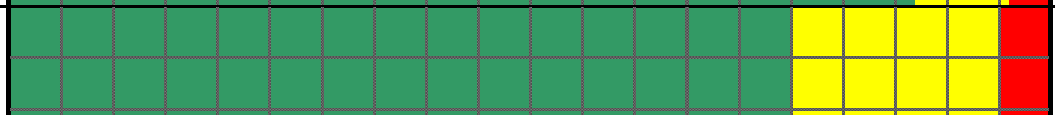
Asset Health Index “Soccer Field”

Asset Type		% of Asset F2006 (Units)	Areas of Concern
Submarine & UG Cables	Civil Structures		Deteriorating manholes & crushed ductbanks
	Equipment		Transformer reduced service life issue
	Feeder Cables		Aging Vancouver cables
	Other		
OH Wires	Poles		Aging poles, Buprestid Beetle Issue
	Equip, Primary wire, svcs, insulators		Automatic splices, Transformer reduced service life issue
	Revenue Meters		2 1/2 element, Schlumb. worm gear, A1R-A demand display, PT/CT mtc, aging meters
	Other		Cutouts, crossarms, anchors, guy wires, Vancouver platforms

Moderate to Good Fair (Attention within 10 years) Attention Now

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BC Hydro's new Asset Replacement Index (ARI)

Asset Replacement Index is the ratio of:

NPV cost for O&M (until End of Life) +

NPV cost Capital replacement (at End of Life) +

NPV of all future O&M & Capital replacements

And

Cost of Capital replacement Now +

NPV cost of all future O&M & Capital replacements

If Asset Replacement Index

≥1 replace now!

>0.8 Red – plan for replacement within 4 years.

>0.5 Yellow – plan for replacement within 10 years.

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A Formula for Asset Replacement

$$ARI = \frac{\sum_{t=0}^{n} O\&M \; + Rplace_{t=n} + \sum_{t=n}^{\infty}\left(O\&M \; + Rplace\right)}{Rplace_{t=0} + \sum_{t=0}^{\infty}\left(O\&M \; + Rplace\right)}$$

All Net Present Value (NPV)

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ARI Considerations

- Data intensive, significant effort (e.g. ~900,000 poles).
- Age data not readily available for all assets (e.g. cables). Need to use proxies, or base on representative sample.
- Provides a long-term Maintenance capital plan for replacement based on established Maintenance and performance expectations.
- Does not provide direct indication of asset Maintenance “needs”. That is, an ARI that is green does not mean one can reduce Maintenance (O&M) spending.
- ARI related to health, but not equal to.

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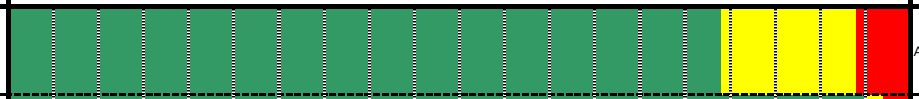
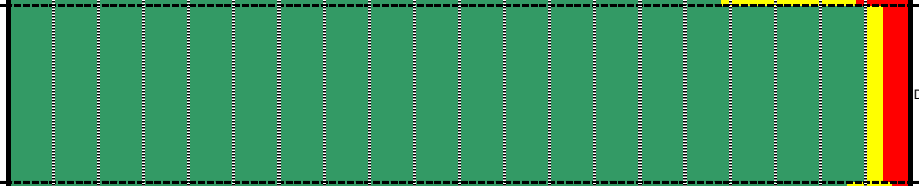
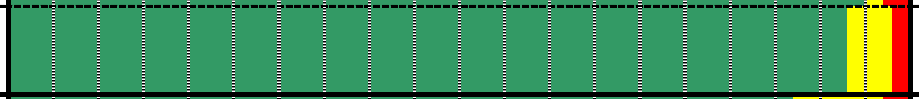
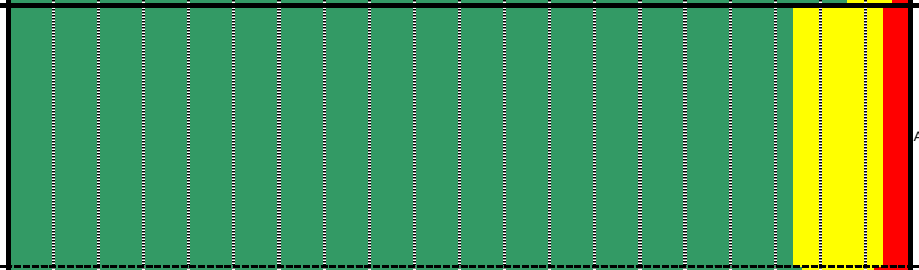
Asset Replacement Index “Soccer Field”

Asset Type		% of Assets F2007 (Units)	Areas of Concern	Replacement $M
UG Distribution Systems	Feeder, Submarine & UD Cables		Aging Vancouver cables	984
	Duct Banks		Deteriorating manholes & crushed ductbanks	2,000
	Equipment			1,038
OH Distribution Systems	Poles		Aging poles	2,964
	Structure Attachments (Crossarms, Guys, Anchors)		Cutouts, crossarms, anchors, guy wires, Vancouver platforms	1,061
	Equipment		Automatic splices, Transformer reduced service life issue	407
	Primary and Secondary Wire			468
				8922

Moderate to Good Fair (Attention within 10 years) Attention Now Total

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AHI presents assets requiring attention, irrespective of cost
ARI is closely tied to LCA and represents the cost

Example: Pole AHI versus ARI

- Based on BC Hydro poles 866,016
- Data on age available. Well established pole T&T program.
- “Health” of poles different if using AHI versus ARI
- BCH Test & Treats ~90,000 poles and renews ~5,500 poles annually.

	AHI	ARI
Green	87%	95%
Yellow	9%	4%
Red	4%	1%

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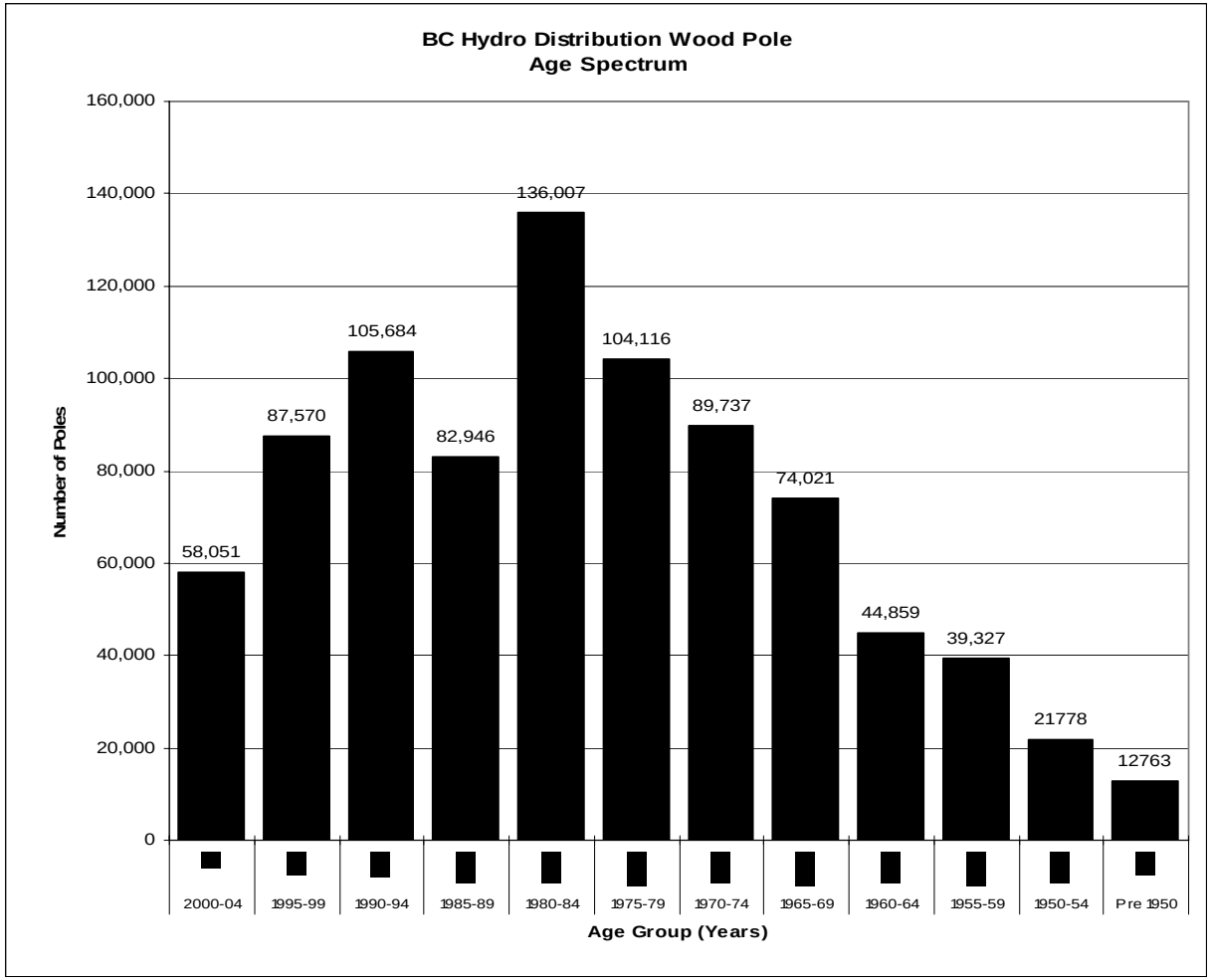

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Poles Set	2000-04	1995-99	1990-94	1985-89	1980-84	1975-79	1970-74	1965-69	1960-64	1955-59	1950-54	Pre 1950
Age Group	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56 +
POLE COUNT TOTALS	58,051	87,570	105,684	82,946	136,007	104,116	89,737	74,021	44,859	39,327	21778	12763

Average Age = 23.83

Next Steps

- ARI calculations recently completed for 8-10 asset types.
- Continue with BOTH expert judgement AHI represented in the soccer field and the new ARI calculation.
- Consider introducing a more rigorous AHI evaluation, to remove subjective judgement.
- Create and implement a plan to gather missing asset age & condition data to be able to accurately calculate ARI.
- Consider how to reduce the level of effort required to complete ARI calculations annually. Automate process.

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Feeder Cable Background

- 1180 feeder cables, *approximately 2000 km* (1240 miles)
- ~55% PILC, ~45% XLPE
- PILC are three-phase (13 kV belted, 400 and 600 KCM)
- Before 1970: Unjacketed. After 1970: PE Jacket
- All feeder cable in concrete encased ducts
- Splices are in concrete manholes
- One feeder can have both PILC-UJ & J segments
- Large majority of failures in manholes or near terminations

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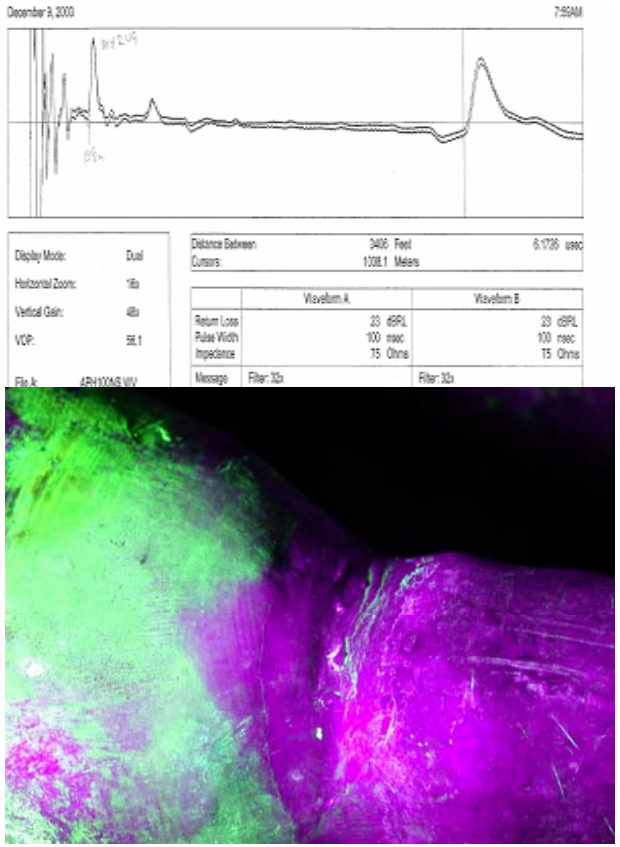
Cable Testing at BC Hydro

- Electrical
  - Leakage Current pico-Ampere Test (LIpATEST©)
  - Time-domain Reflectometry (TDR)
  - Partial Discharge (Ultrasonic)
- Physical
  - Hardness test
  - Dye Penetrant Test
  - Visual Inspection Test



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Cable Strategy Pre-2004

- Based on failure history and available condition tests
  - Most failures with PILC – unjacketed
  - Conclusion – reached burnout of “bathtub” curve
  - Strategy – blanket replacement of PILC – UJ
  - Result – some perfectly good cable being replaced!

Cable Asset Health Methodology

- Established Detailed Condition Assessment (DCA) ranking system
  - DCA Ranking 1&2: Severe Degradation
  - DCA Ranking 3: Moderate Degradation
  - DCA Ranking 4: Minor Degradation
  - DCA Ranking 5: No Degradation

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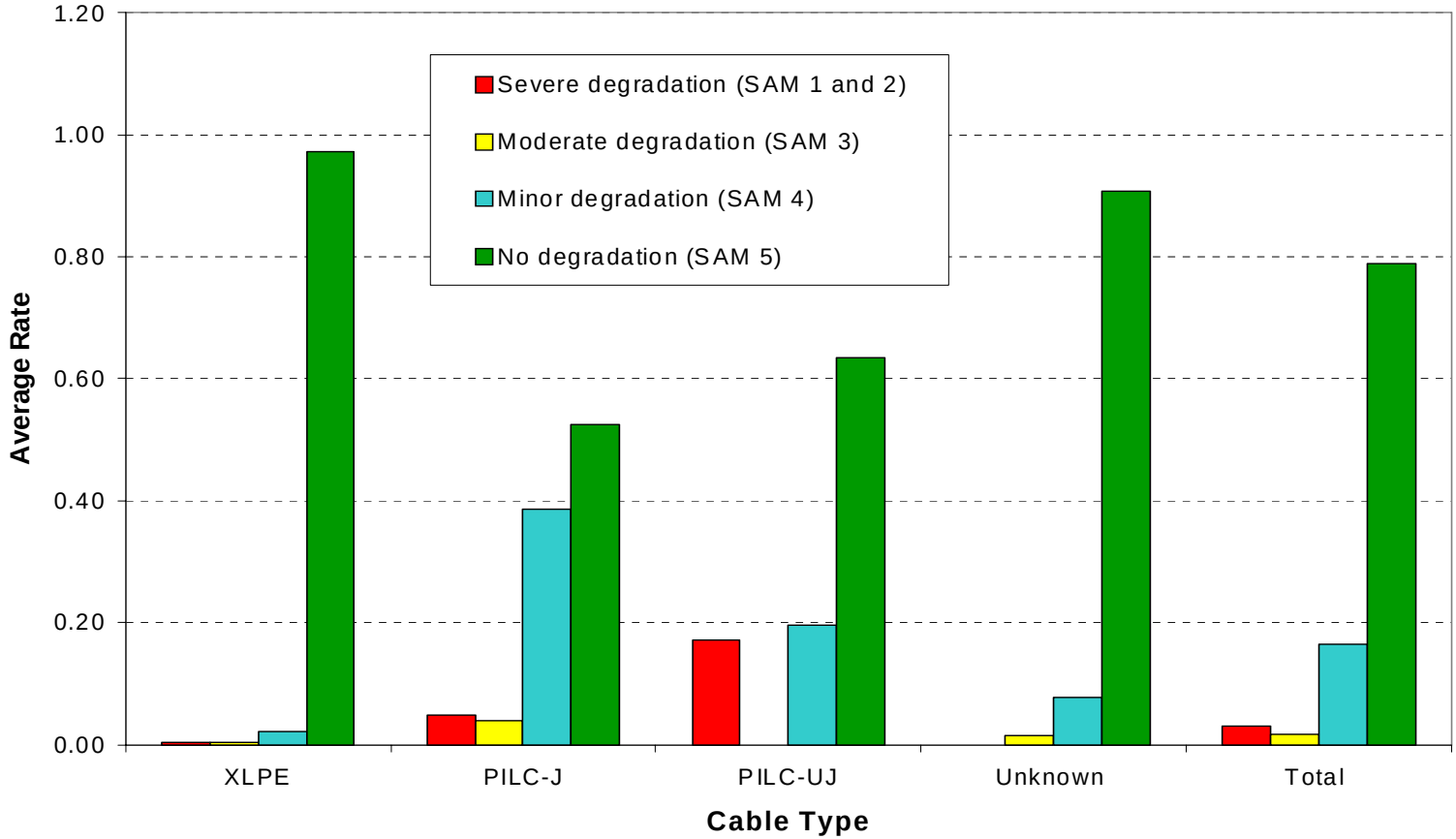
Cable Asset Health Analysis



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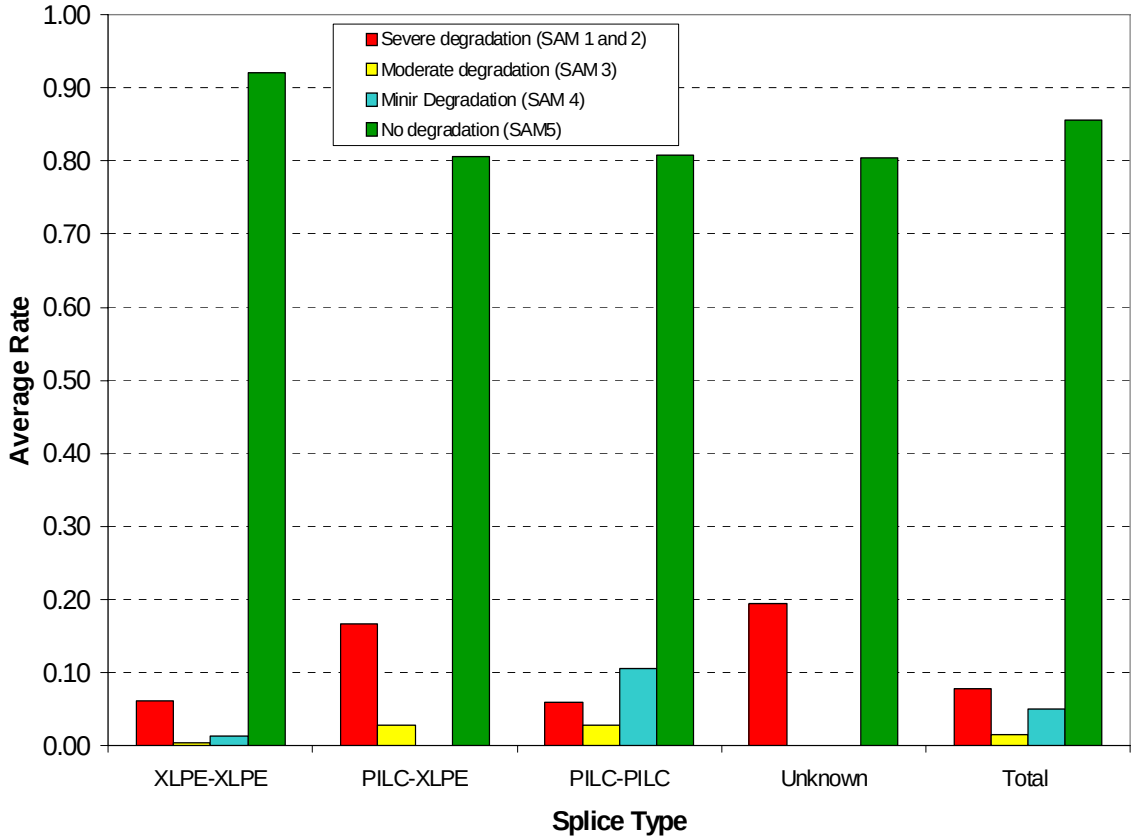
- In average, 80% of the cable sections are in good condition
- The average rate of severe degradation/defects of cables is 3%.
- PILC UJ cables have the highest severe degradation/defect.

Cable Asset Health Analysis



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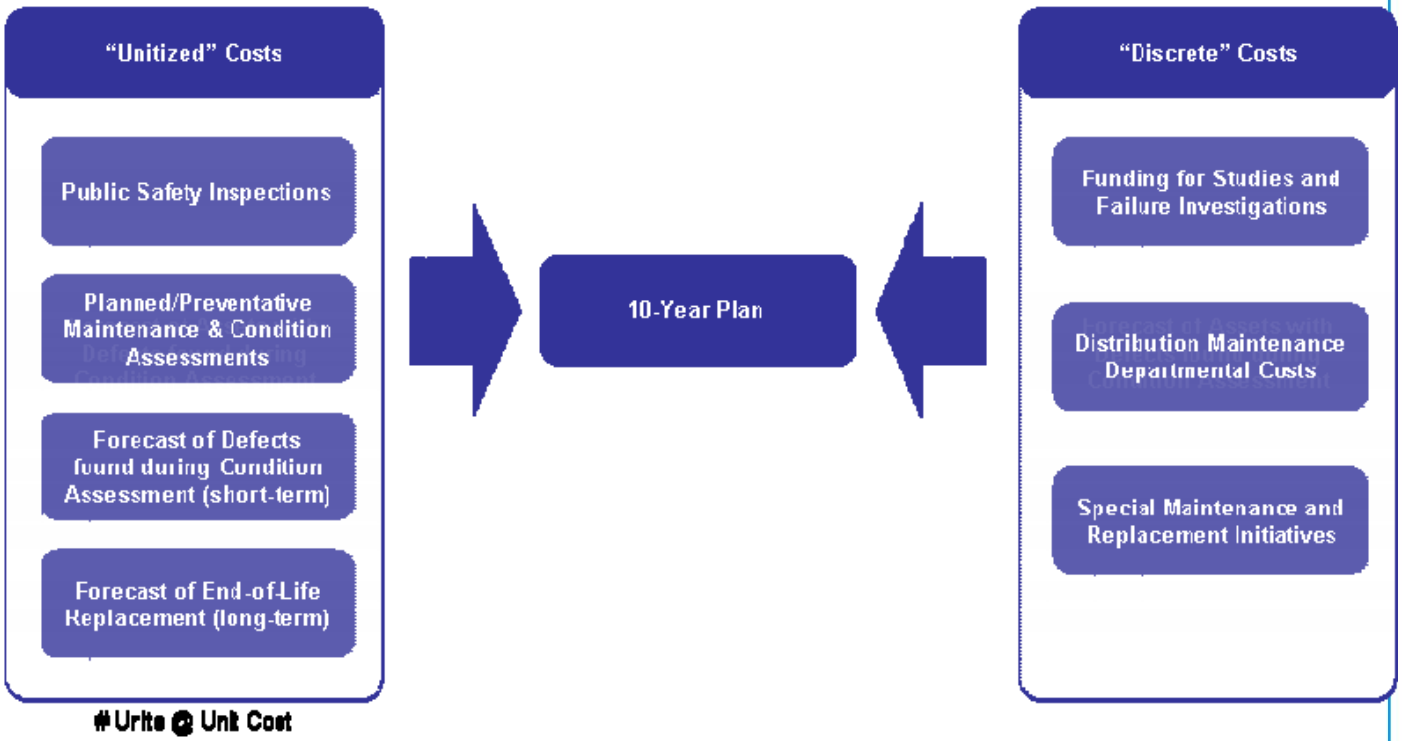
- In average, 85% of the splices are in good condition
- The average rate of degradation/defects of splices is 7.9%.
- Transition splices have the highest severe degradation /defect rate.

Build Plan



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Execute Plan

The processes used to execute the plan are also considered important aspects of the overall planning process:

- Obtaining budget approval;
- Implementing work plans;
- performance and modifying plans accordingly

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Evaluate Performance

Analysis includes:

- Standard costs per unit work compared to actuals;
- DODW failure and trouble call information are analyzed for equipment failure causing outages;
- SAM defect data is reviewed to determine if process has desired affect over time;
- Safety incidents and near misses are reviewed to determine if design standards, work practices, or other factors should be changed;
- Environmental incidents and compliance are monitored.

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Conclusions

- DM's 10-Year plan provides a long-term forecast of OMA and capital replacement spending that is deemed necessary to maintain a high level of performance in BC Hydro's distribution network.
- Continue with subjective and audited asset health evaluations to meet safety and due diligence requirements.
- Continue to expand condition assessment and build asset data profiles for various assets.
- Use ARI and LCA to improve the effectiveness of maintenance and replacement spending in delivering performance expectations.
- Include customer needs and expectations in managing asset health investments.
- Move to an investment perspective of asset health and demonstrate the opportunity to reduce investment while meeting performance expectations.

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Thank you

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