Managing the Life Cycle Costs of Gravel Runways

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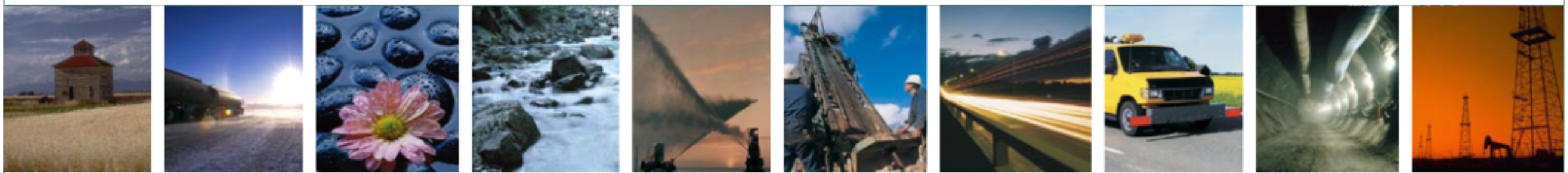

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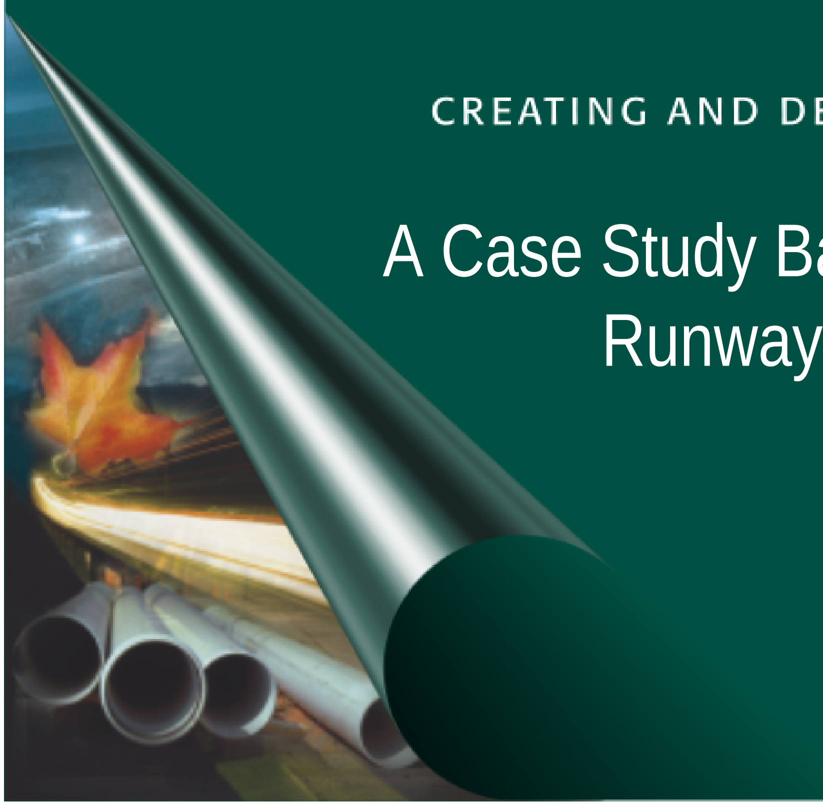
A Case Study Based on 44 Gravel Surfaced Runways in Canada's North



Contents

- Issues and Challenges
- Background to the Gravel Surface Management Study
- Scope of Gravel Road Management Study
- Data Collection
- Gravel Consumption Prediction Modeling
- Analysis Inputs
- Analysis Results
- Questions

Typical Issues Relating to Gravel Surfaces

- The usable onsite gravel supplies are being depleted;
- Other onsite resources may become unavailable for environmental reasons;
- Offsite sources are many times more expensive;
- With increased usage, there will be intensified requirements for Gravel resources;
- Owner Agencies need to know how to minimize and quantify future gravel requirements.

Institutional Issues Related to Canada's North

- Staff turnover
- Level of effort required for implementation
- Difficulty in establishing historical costs
- Creation of two governments
- Amalgamation of departments

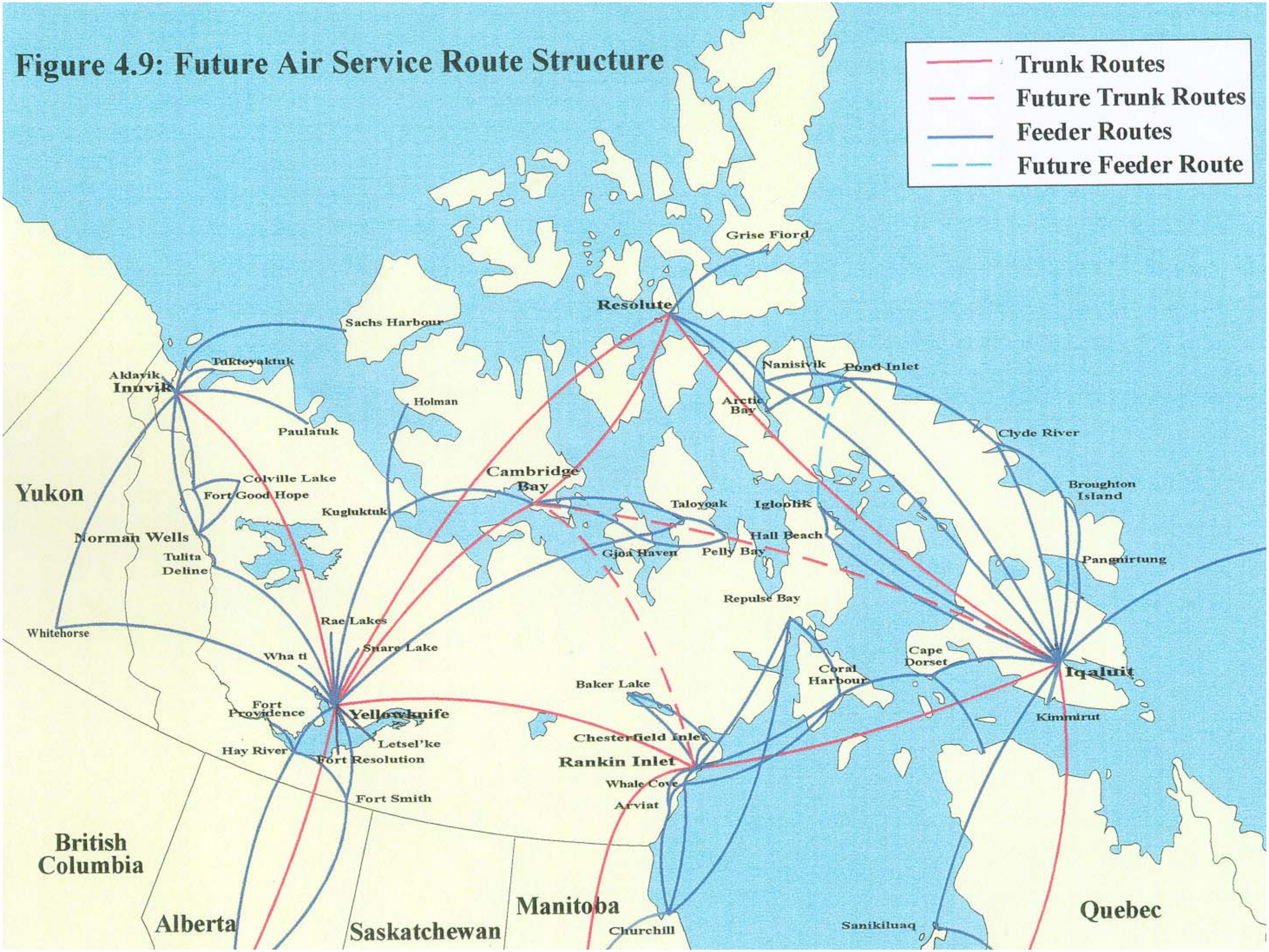


Figure 4.9: Future Air Service Route Structure
Trunk Routes
Future Trunk Routes
Feeder Routes
Future Feeder Route
Grise Fiord
Resolute
Sachs Harbour
Tuktoyaktuk
Aklavik
Inuvik
Holman
Paulatuk
Nanisivik
Pond Inlet
Arctic Bay
Clyde River
Cambridge Bay
Colville Lake
Fort Good Hope
Yukon
Kugluktuk
Taloyoak
Igloolik
Broughton Island
Norman Wells
Tulita
Deline
Hall Beach
Gjoa Haven
Pelly Bay
Pangnirtung
Repulse Bay
Rae Lakes
Whitehorse
Snare Lake
Wha ti
Cape Dorset
Coral Harbour
Iqaluit
Baker Lake
Fort Providence
Yellowknife
Kimmirut
Letsel'ke
Chesterfield Inlet
Hay River
Fort Resolution
Rankin Inlet
Whale Cove
Fort Smith
Arviat
British Columbia
Manitoba
Quebec
Alberta
Saskatchewan
Churchill
Sanikiluaq

Distribution of Airport Characteristics

TC Code	Length	Asphalt	Gravel
1	< 2600 ft	0	6
2	2600-4000 ft	0	19
3	4000-6000 ft	1	18
4	> 6000 ft	7	1
	TOTAL	**8**	**44**

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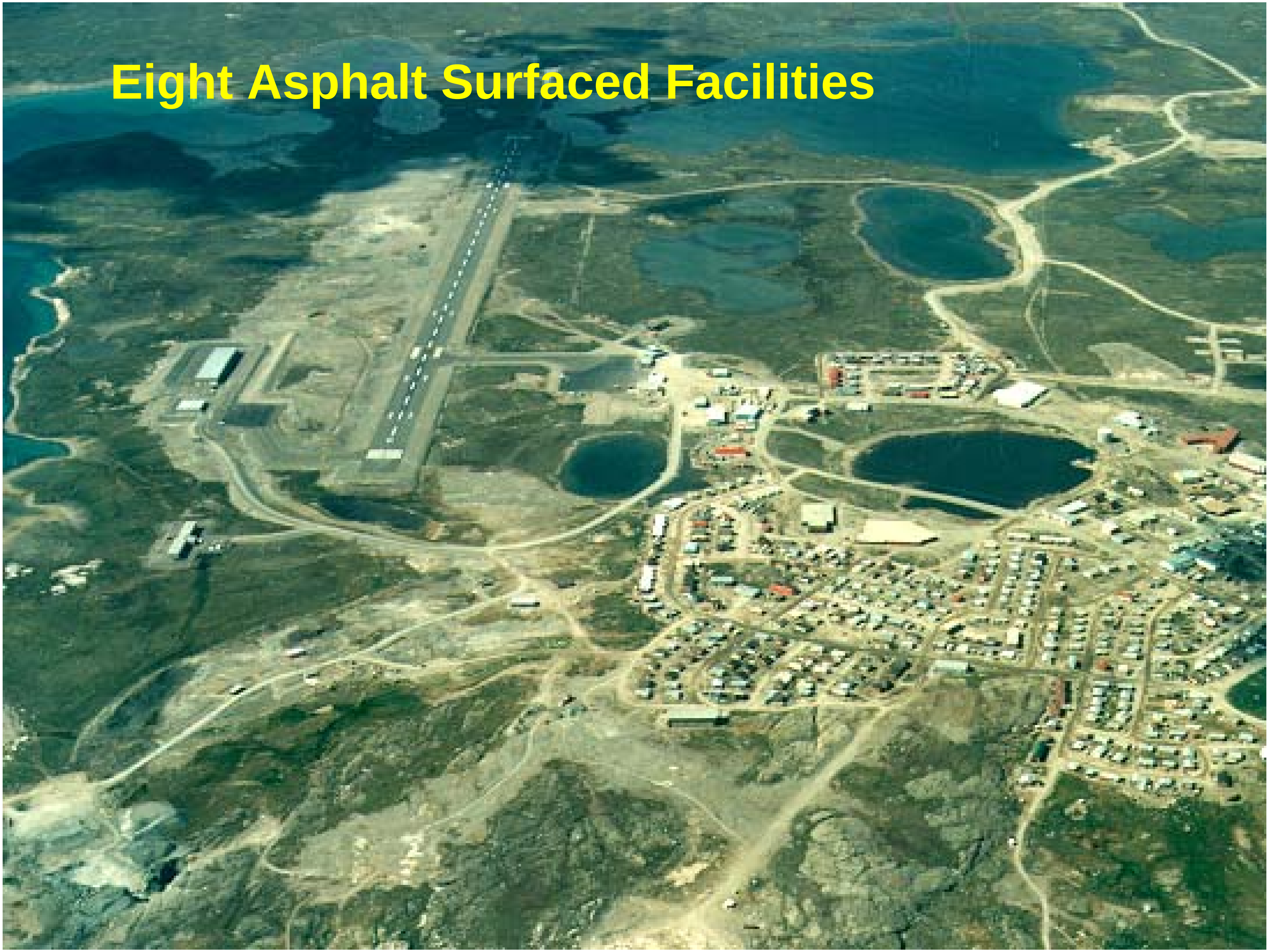
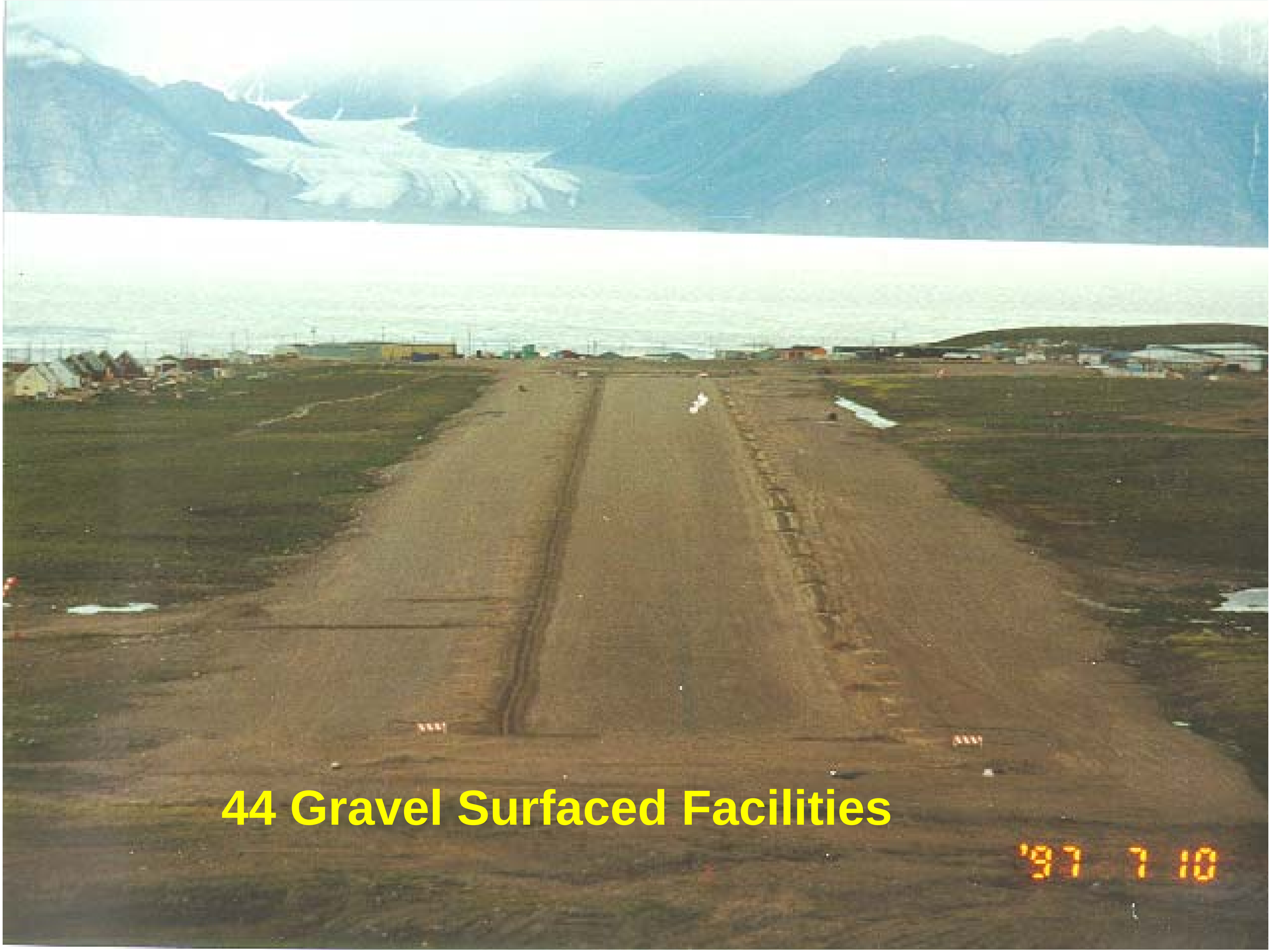
Unique to this case study

- Network of facilities vs a single facility system
- AC and Gravel performance models
- Diversity
  - Traffic
  - Size/classification code
  - Climate
- Road Accessible/Air accessible
  - Construction costs
- Territorial Division Midproject

Figure 5.1: GNWT Airport System

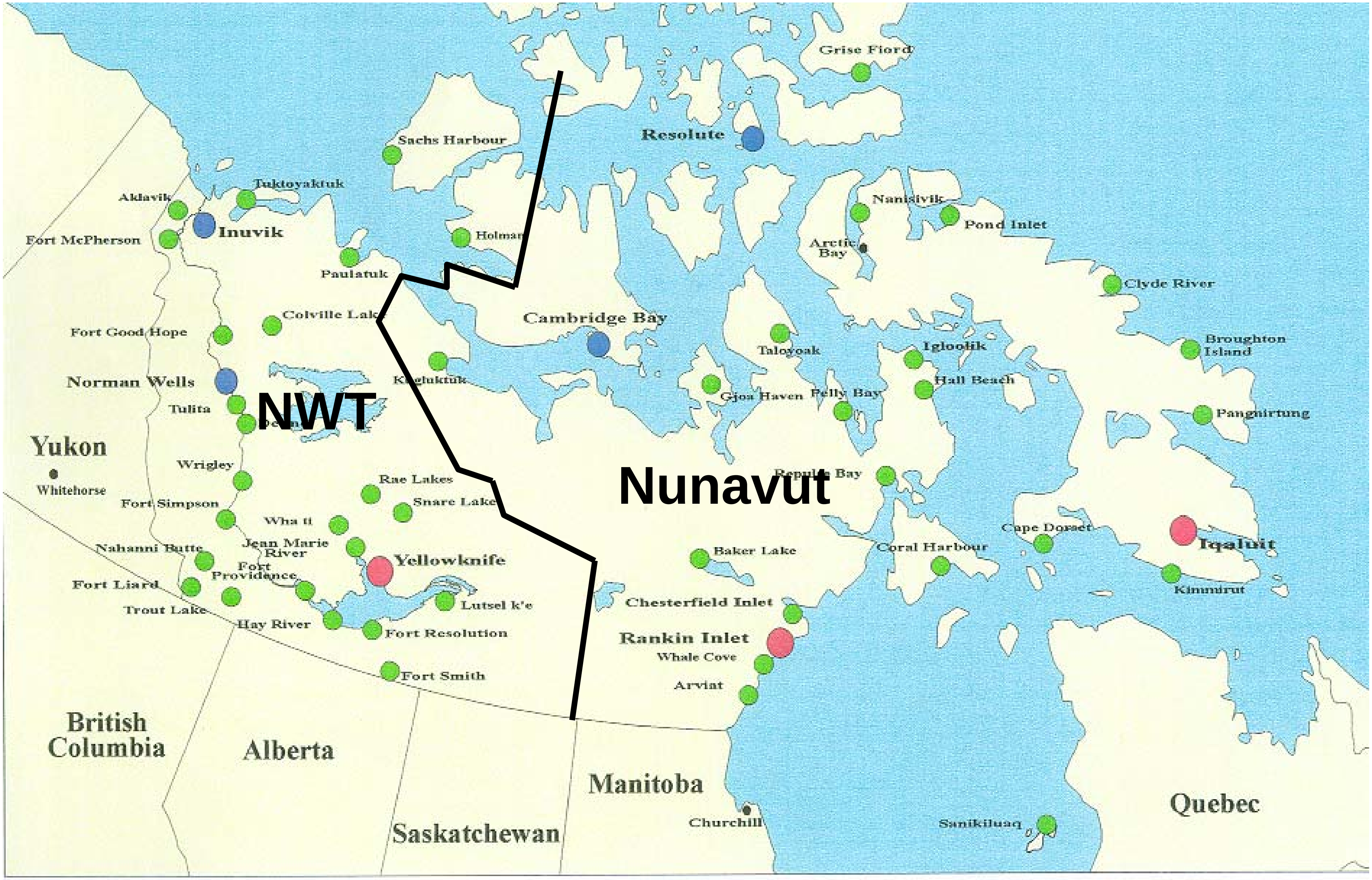
Eight Asphalt Surfaced Facilities

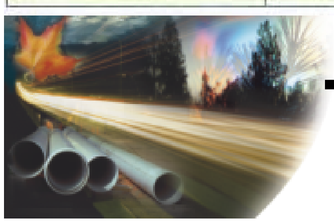



44 Gravel Surfaced Facilities
'97 7 10


Airports have diverse roles in the Arctic
'97 8 27

Air is the only access to many communities





Territorial Division - April 1st, 1999

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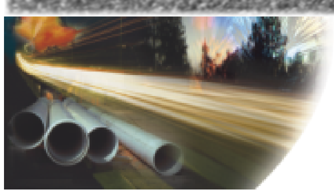
Data Collection Challenges

- Northern Data Collection
  - Distance
  - Short Season
  - Accessibility/Travel costs
- Unique Surface Distresses
  - Thermal distresses
  - Very little fatigue distress



Surface Distress Survey Vehicle

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Surface Distress Measurements Based on ASTM D 5340 - (PCI)

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D 5340

X5. BLANK FORMS

AIRFIELD ASPHALT PAVEMENT CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT	SKETCH:
BRANCH 03-26 SECTION 5H SAMPLE UNIT 9 SURVEYED BY_____ DATE_____ SAMPLE AREA_____	

1. Alligator Cracking	5. Depression	9. Oil Spillage	13. Rutting
2. Bleeding	6. Jet Blast	10. Patching	14. Shoving from PCC
3. Block Cracking	7. Jt. Reflection (PCC)	11. Polished Aggregate	15. Slippage Cracking
4. Corrugation	8. Long. & Trans. Cracking	12. Raveling/Weathering	16. Swell

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
10L	7.5									7.5		
8L	65									65		
5L	30m²									30		
12L	30									30		

FIG. X5.1 Flexible Pavement Condition Survey Data Sheet for Sample Unit

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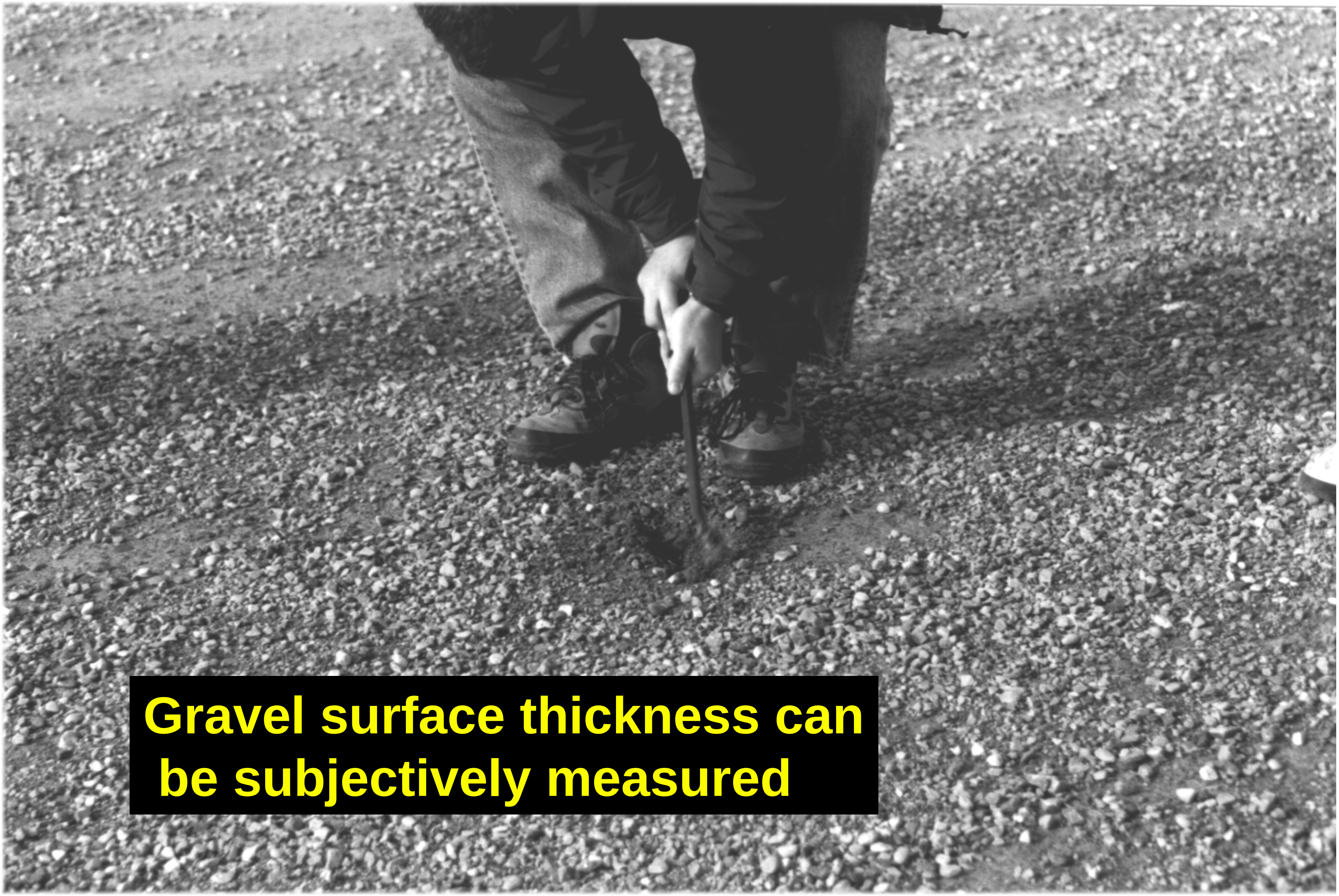
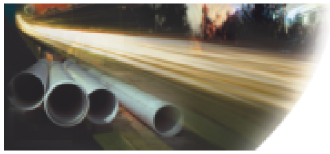
Surface Distresses in Arctic Climates

- Prevalent
  - Block (thermal) Cracking
  - Swell/Depressions
  - Deep seated Transverse Cracks
- Rare
  - Rutting
  - Fatigue cracking

Individual Gravel Distresses are often masked by on-going maintenance activities


Gravel surface thickness can
be subjectively measured



LCCA Requirements

- Model both AC and Gravel performance
- Pavement performance models specific to each site to accommodate the diversity of site conditions
- Need to consider both Capital and O&M budgets
- Need to forecast maintenance costs

Variables that need to be Modeled

- Traffic
  - Growth
  - Changes in use
- Asphalt
  - L&T Cracking
  - Block Cracking
  - Weathering/Raveling
  - Remaining Strength
  - Pavement Condition Index (PCI)
- Gravel Surfaces
  - Surface Thickness
  - Stockpile Volume
  - Remaining Service Life

Modeling Software (dTIMS CT)

- User definable Performance Models
  - Crack models
  - Roughness models
  - Gravel models
- User Sustainable
  - Users can redefine/update
    - Models
    - Costs
    - Budgets etc.
- Multiple Budget Categories

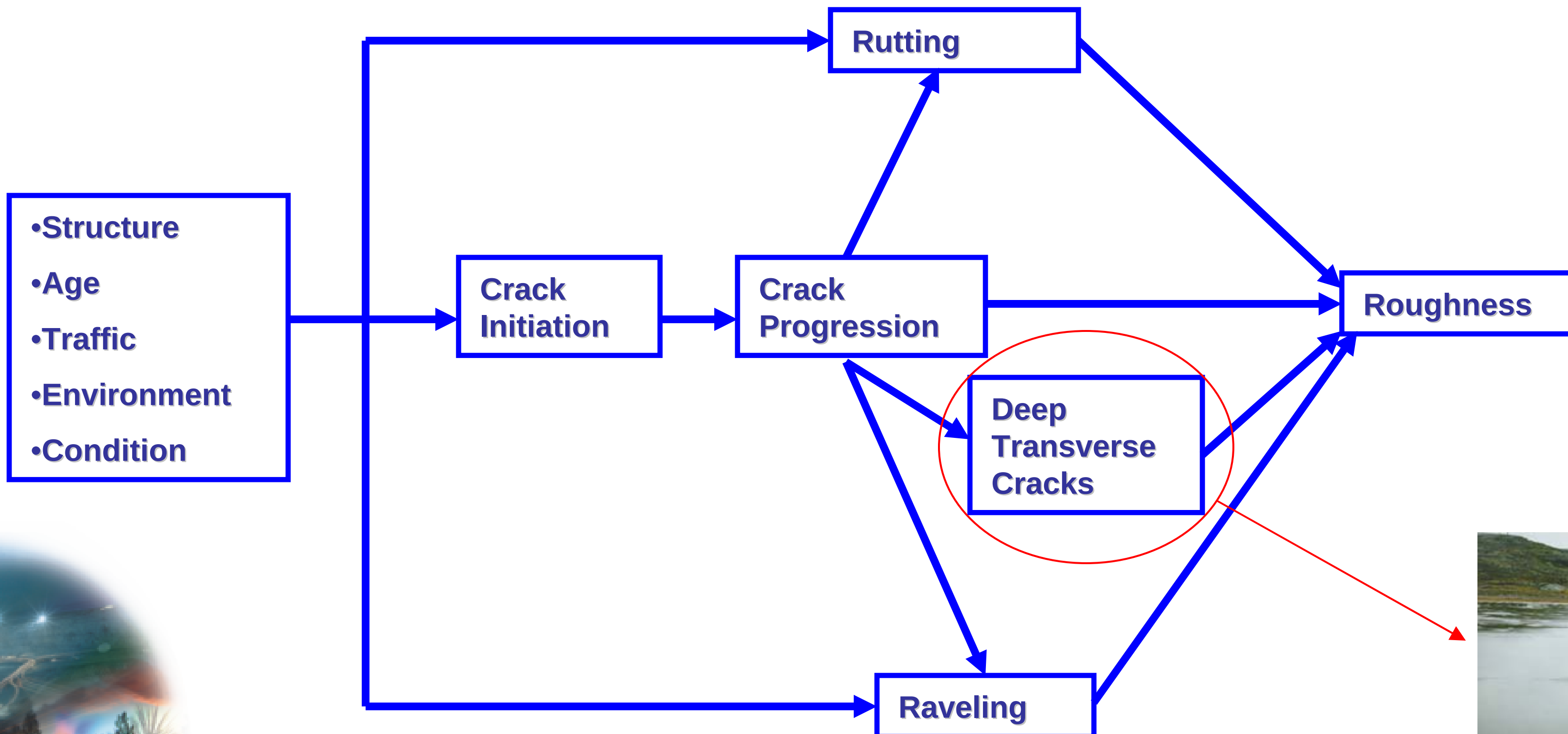
Surfacing Gravel Thickness as a Measure of Network Health

Condition	Thickness	To ACA	Colour
V Good	250 mm	400 mm	
Good	200 mm	250 mm	
Fair	150 mm	200 mm	
Poor	100 mm	150 mm	
V Poor	0 mm	100 mm	


Historic rate of gravel loss can be
calculated and future rates of loss projected

ACP Distress Prediction Modeling

Pavement Performance - Distress Prediction Modeling



Gravel Loss Rate Prediction Modeling

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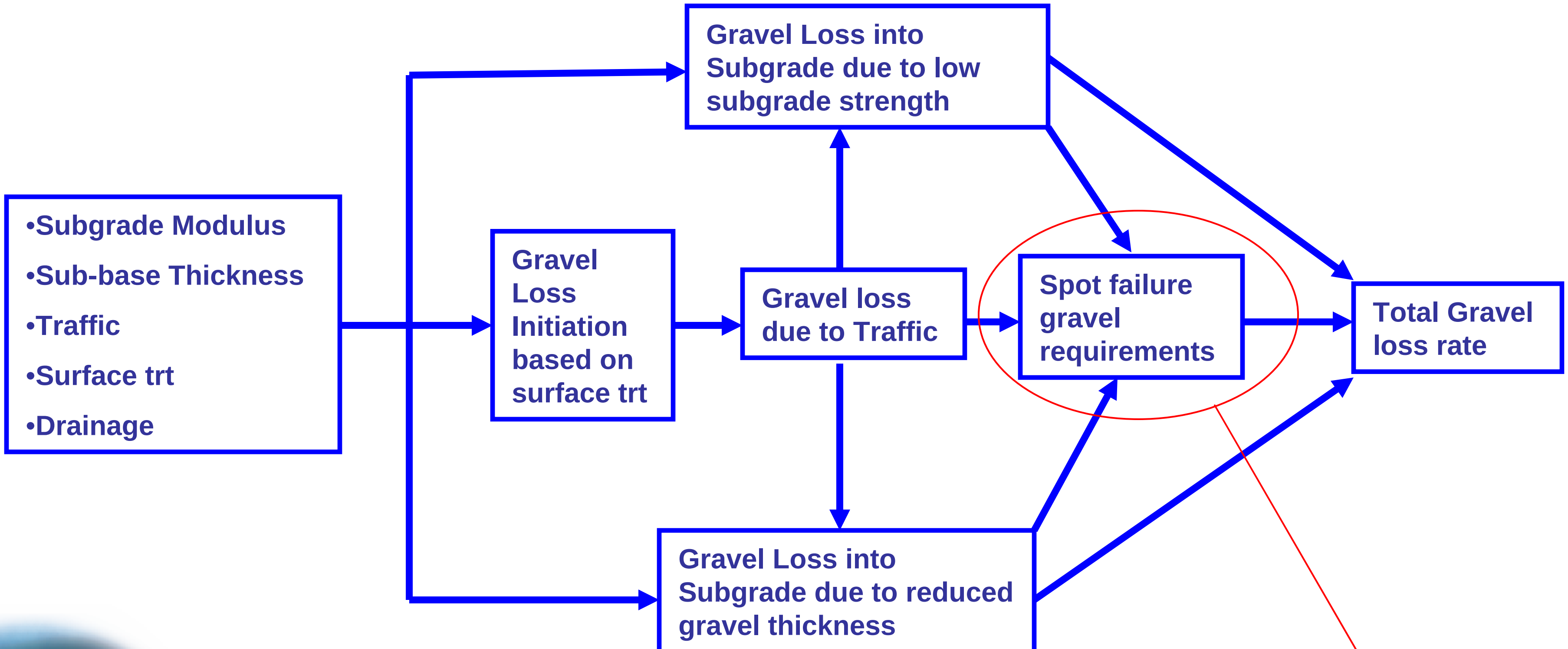
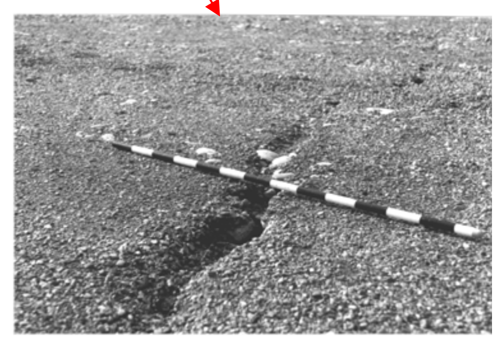
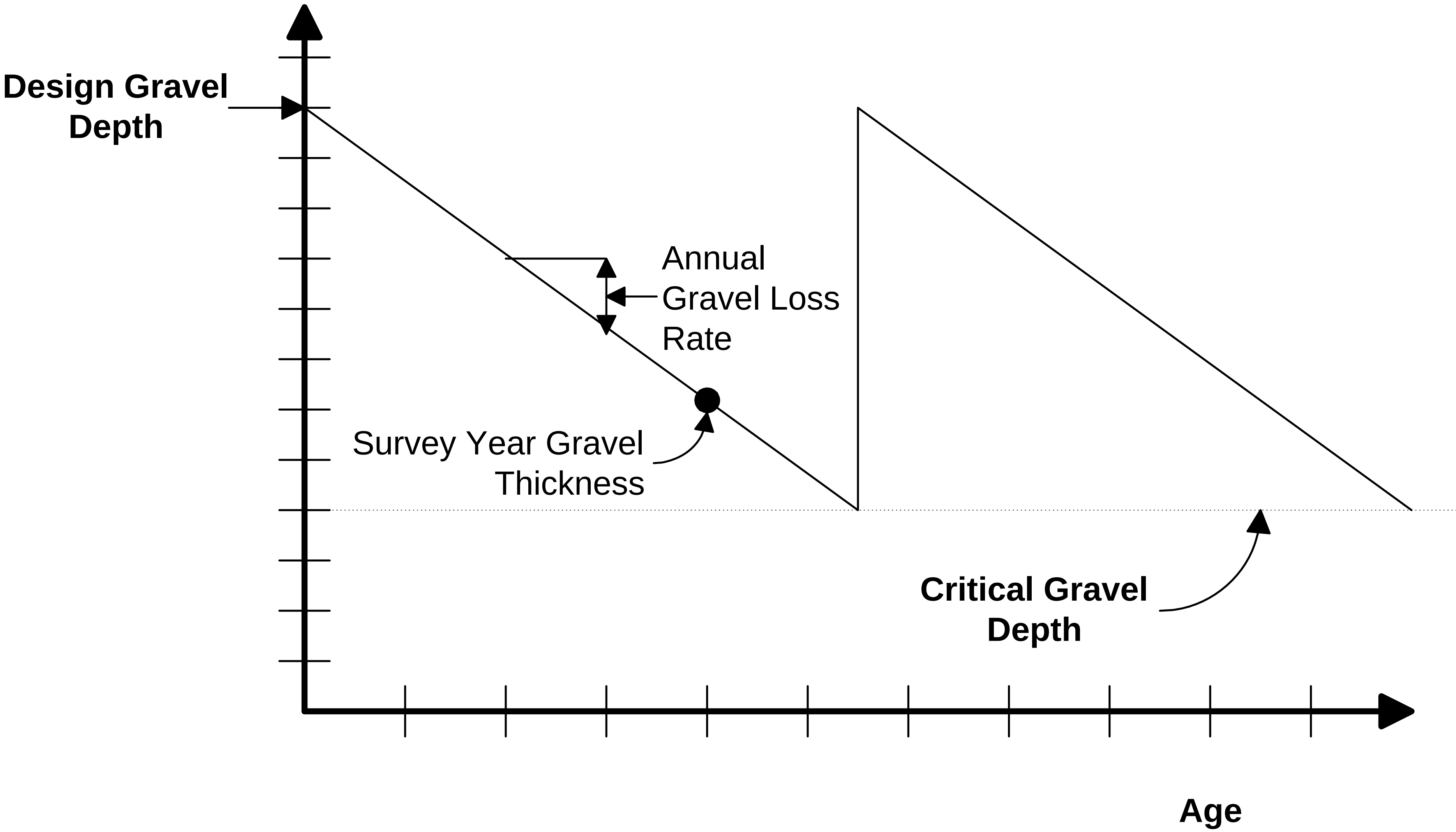




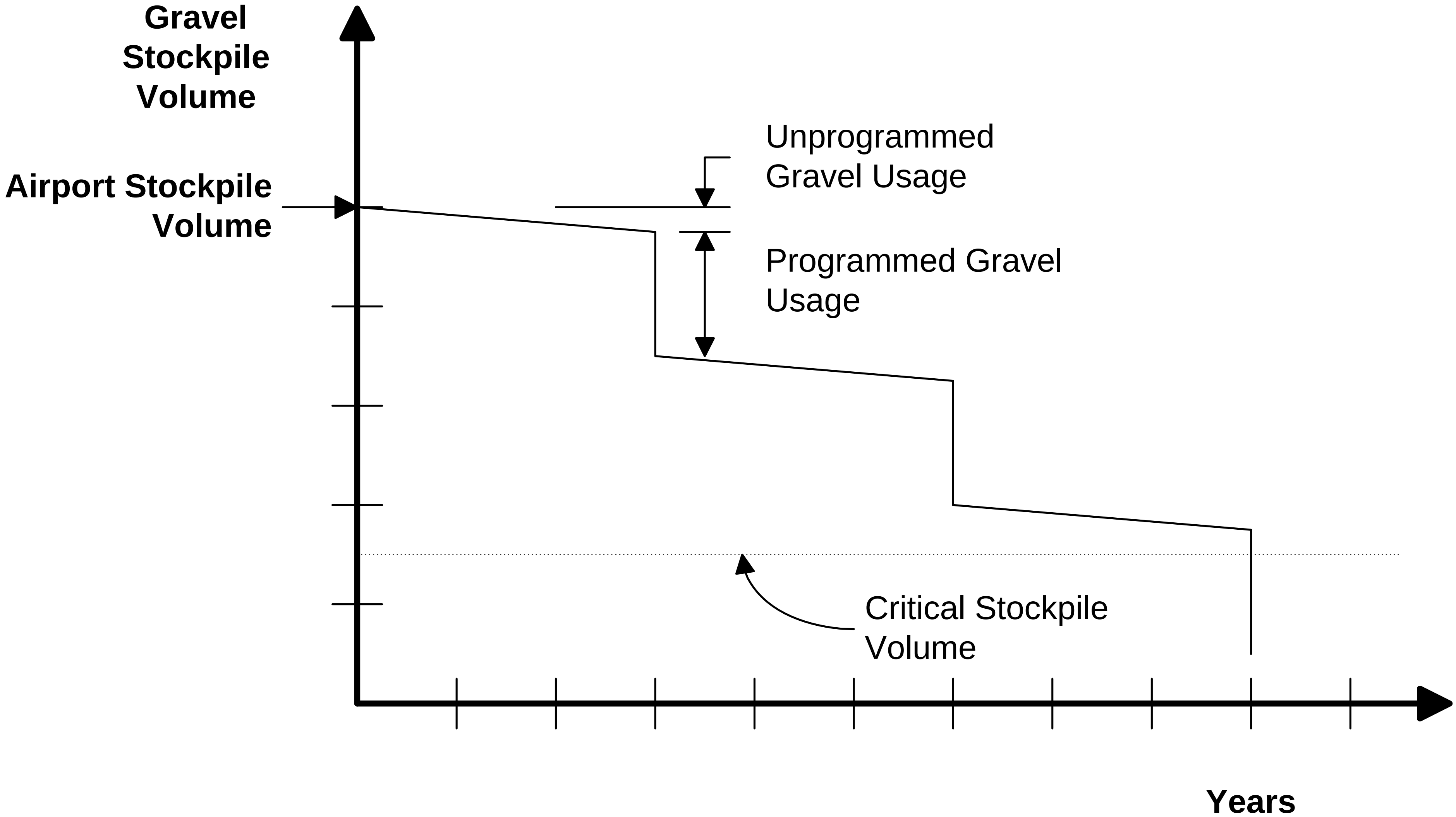
Calibration of Gravel Loss Rate

- If historically 1,000 tonnes of Gravel for thickness replenishment and spot repairs at a given site/year - the models are calibrated such that 1,000 tonnes are used in year 1 for thickness replenishment and spot repairs)
- Each site has a different set of gravel loss attribute components
- Loss rate then used to back calculate loss component for traffic, subgrade modulus, sub-base thickness and surfacing structure.
- Once a component based loss rate is established, it can be used to forecast future loss rates under varying conditions.

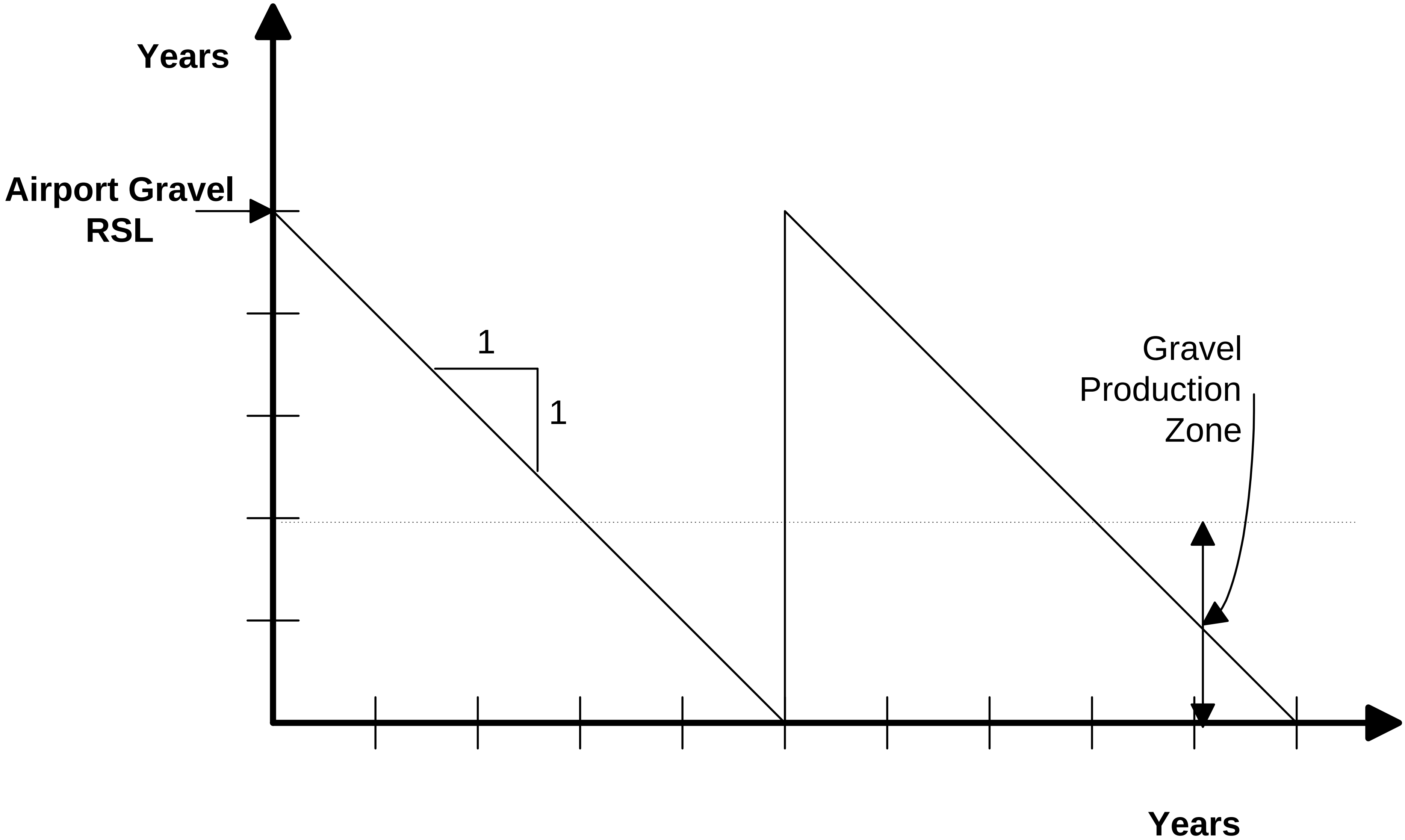
Gravel Depth vs Age



Gravel Stockpile Volume vs Age



Gravel Remaining Service Life



Analysis Inputs

Maintenance/Rehabilitation Treatments and Costs

Treatment	Unit Cost
• Patroling/Blading	$0.05/m^2
• Spot Repairs	$35/m^2
• Re-Gravelling	$35/tonne
• Gravel Production	$10-$100/m^3

LCC Calculation

$LCCpv = CC + OCpv + (R+M)Cpv - SCpv$

Where:

$\mathbf{LCC_{pv}}$	=	Present Value of all Life Cycle Costs
CC	=	Initial construction costs of the pavement structure
$\mathbf{OC_{pv}}$	=	Present value of the operating costs to the users/owners of the pavement
$\mathbf{(R+M)C_{pv}}$	=	Present value of the sum of all rehabilitation and maintenance costs over the analysis period.
$\mathbf{SC_{pv}}$	=	The present value of the residual pavement structure components at the end of the analysis period (also called salvage value)

Simplified LCC for Existing Pavements

$$LCCpv = (R+M)Cpv$$

LCCpv is often referred to as Present Value Cost or PVCost

Analysis

The LCCA Evaluates Several Strategies for Each Gravel Segment (including aprons, taxiways and itinerant parking)

- Strategy is comprised of combinations of individual treatments and treatment application timings
- For a given segment there are hundreds potential preservation strategies.
- Each strategy has a life-cycle cost measured in present worth at a discount rate of 4%
- Each strategy has a benefit measured as the present worth of the value of the gravel in-place in each year of the life cycle

Analysis Scenarios

Typically Conduct Optimization Analysis for Several Funding Scenarios

- Minimum Cost to keep the facility open – trades off re-gravelling with the cost of spot repairs (high maintenance costs)
- Current funding levels
- Unconstrained funding in order to maximize the asset value/cost ratio
- Evaluate the LCCA effect of conversion any segment to ACP surface
- Optimal funding to provide a uniform funding scheme while maximizing the asset value/cost ratio

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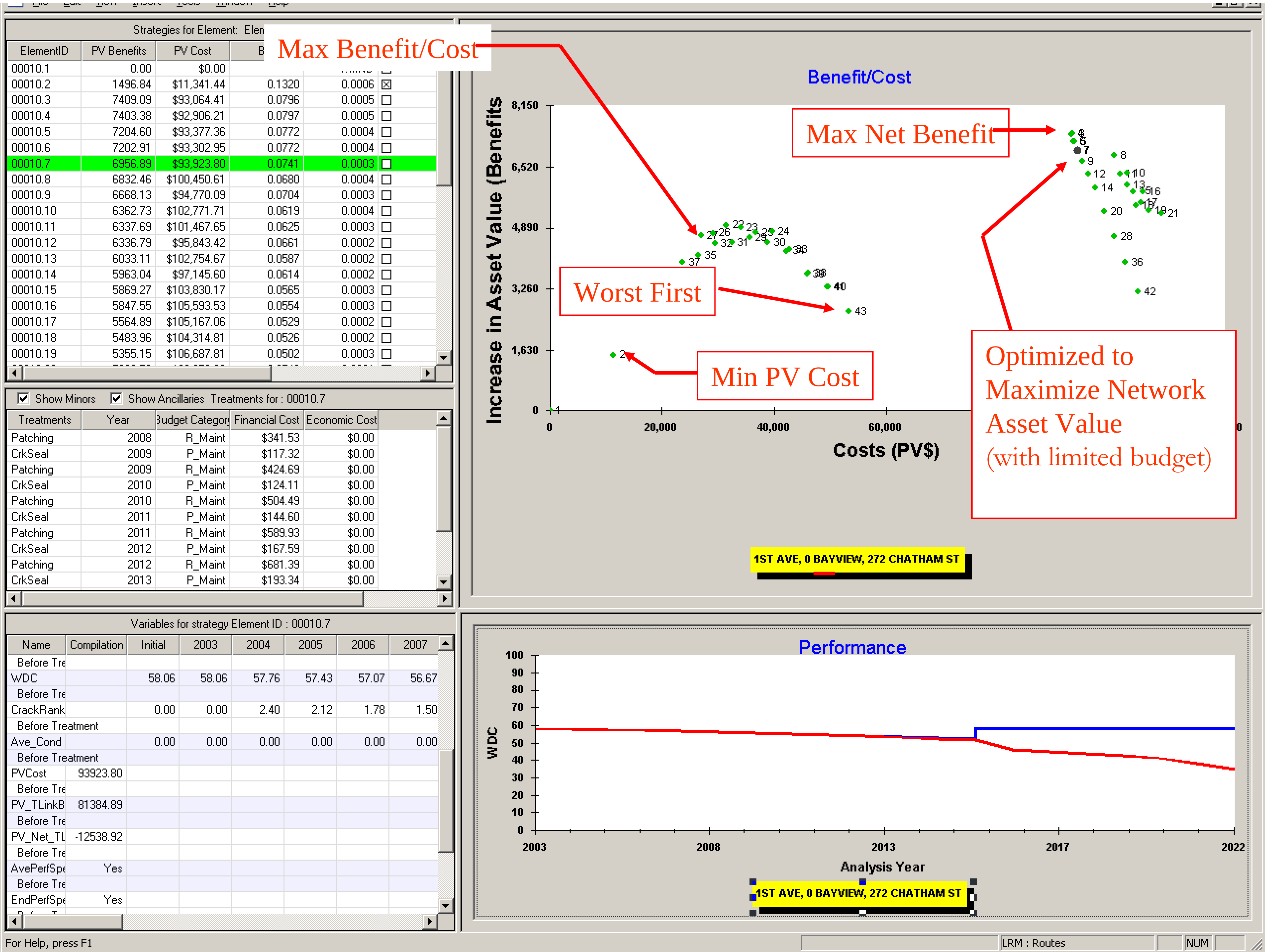
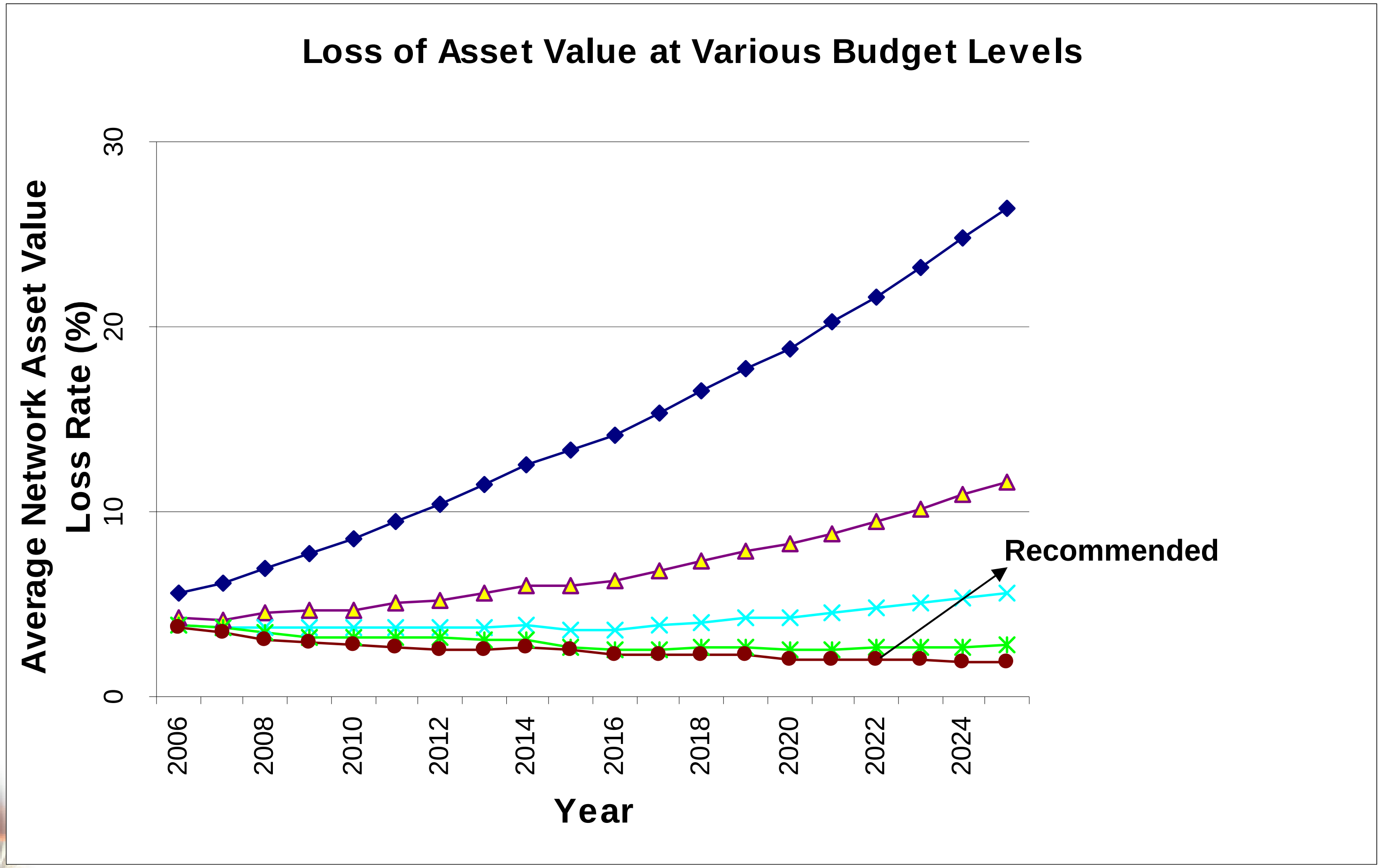


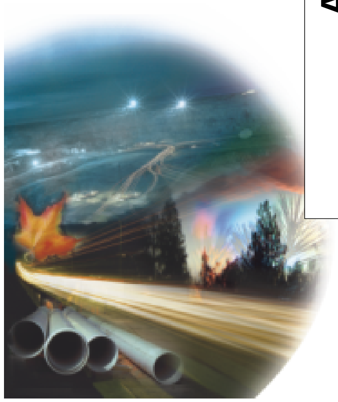
ElementID	PV Benefits	PV Cost	B		
00010.1	0.00	$0.00			
00010.2	1496.84	$11,341.44	0.1320	0.0006	☒
00010.3	7409.09	$93,064.41	0.0796	0.0005	☐
00010.4	7403.38	$92,906.21	0.0797	0.0005	☐
00010.5	7204.60	$93,377.36	0.0772	0.0004	☐
00010.6	7202.91	$93,302.95	0.0772	0.0004	☐
00010.7	6956.89	$93,923.80	0.0741	0.0003	☐
00010.8	6832.46	$100,450.61	0.0680	0.0004	☐
00010.9	6668.13	$94,770.09	0.0704	0.0003	☐
00010.10	6362.73	$102,771.71	0.0619	0.0004	☐
00010.11	6337.69	$101,467.65	0.0625	0.0003	☐
00010.12	6336.79	$95,843.42	0.0661	0.0002	☐
00010.13	6033.11	$102,754.67	0.0587	0.0002	☐
00010.14	5963.04	$97,145.60	0.0614	0.0002	☐
00010.15	5869.27	$103,830.17	0.0565	0.0003	☐
00010.16	5847.55	$105,593.53	0.0554	0.0003	☐
00010.17	5564.89	$105,167.06	0.0529	0.0002	☐
00010.18	5483.96	$104,314.81	0.0526	0.0002	☐
00010.19	5355.15	$106,687.81	0.0502	0.0003	☐

Treatments	Year	Budget Category	Financial Cost	Economic Cost
Patching	2008	R_Maint	$341.53	$0.00
CrkSeal	2009	P_Maint	$117.32	$0.00
Patching	2009	R_Maint	$424.69	$0.00
CrkSeal	2010	P_Maint	$124.11	$0.00
Patching	2010	R_Maint	$504.49	$0.00
CrkSeal	2011	P_Maint	$144.60	$0.00
Patching	2011	R_Maint	$589.93	$0.00
CrkSeal	2012	P_Maint	$167.59	$0.00
Patching	2012	R_Maint	$681.39	$0.00
CrkSeal	2013	P_Maint	$193.34	$0.00

Name	Compilation	Initial	2003	2004	2005	2006	2007
Before Tre							
WDC		58.06	58.06	57.76	57.43	57.07	56.67
Before Tre							
CrackRank		0.00	0.00	2.40	2.12	1.78	1.50
Before Treatment							
Ave_Cond		0.00	0.00	0.00	0.00	0.00	0.00
Before Treatment							
PVCost	93923.80						
Before Tre							
PV_TLinkB	81384.89						
Before Tre							
PV_Net_TL	-12538.92						
Before Tre							
AvePerfSpe	Yes						
Before Tre							
EndPerfSpe	Yes						

Analysis Results at Various Budget Levels





Analysis Results

Cost Comparison of Various Budget Levels for 20 year Period

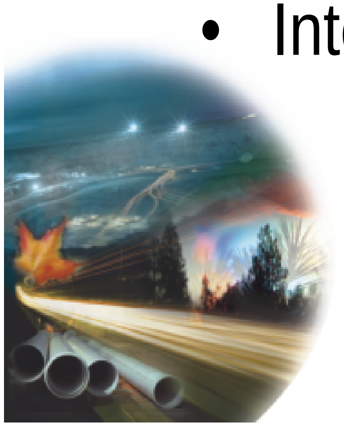
	Budget Category	Total Cost 20 yrs ($Million)	PV Cost 20yrs ($Million)	Average Gravel thickness 2020 mm	Asset Value in 2020 ($Million)
	Minimum Cost (all treatments)	$82.2	$59.7	207	$23.7
*	$4.5 Million (all treatments)	$96.9	$67.5	372	$43.2
**	Minimum Cost (gravel only)	$94.4	$67.5	217	$24.9
	$4.5 Million (gravel only)	$102.3	$71.1	321	$36.6

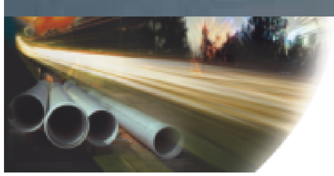
* Recommended Scenario

**Current Practices

Benefits

- Fundamental part of rationalizing OM&R program
- Up to date status of network health
- Standardizing/Automating inspection and condition monitoring
- Provides managers with a better understanding of the network
- Tool for justifying funding requests
- Integral part of an agencies due diligence process





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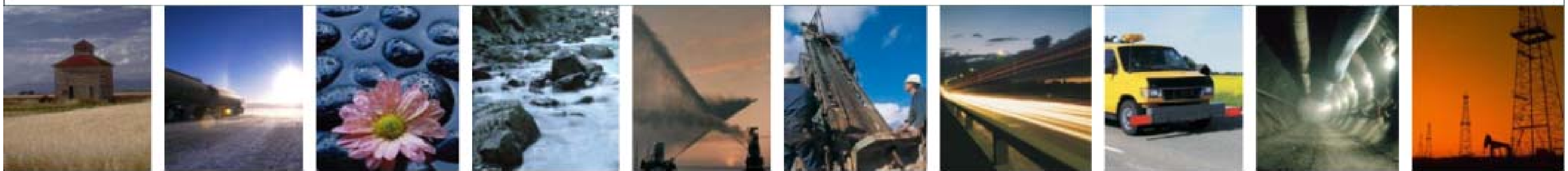

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