WORLD HEAVY OIL CONGRESS 2016
Calgary, Alberta, Canada

New Oil Sands Technology to Meet the Challenges of Climate Change and Tailings Management

Titanium Corporation

WHOC16-[260]

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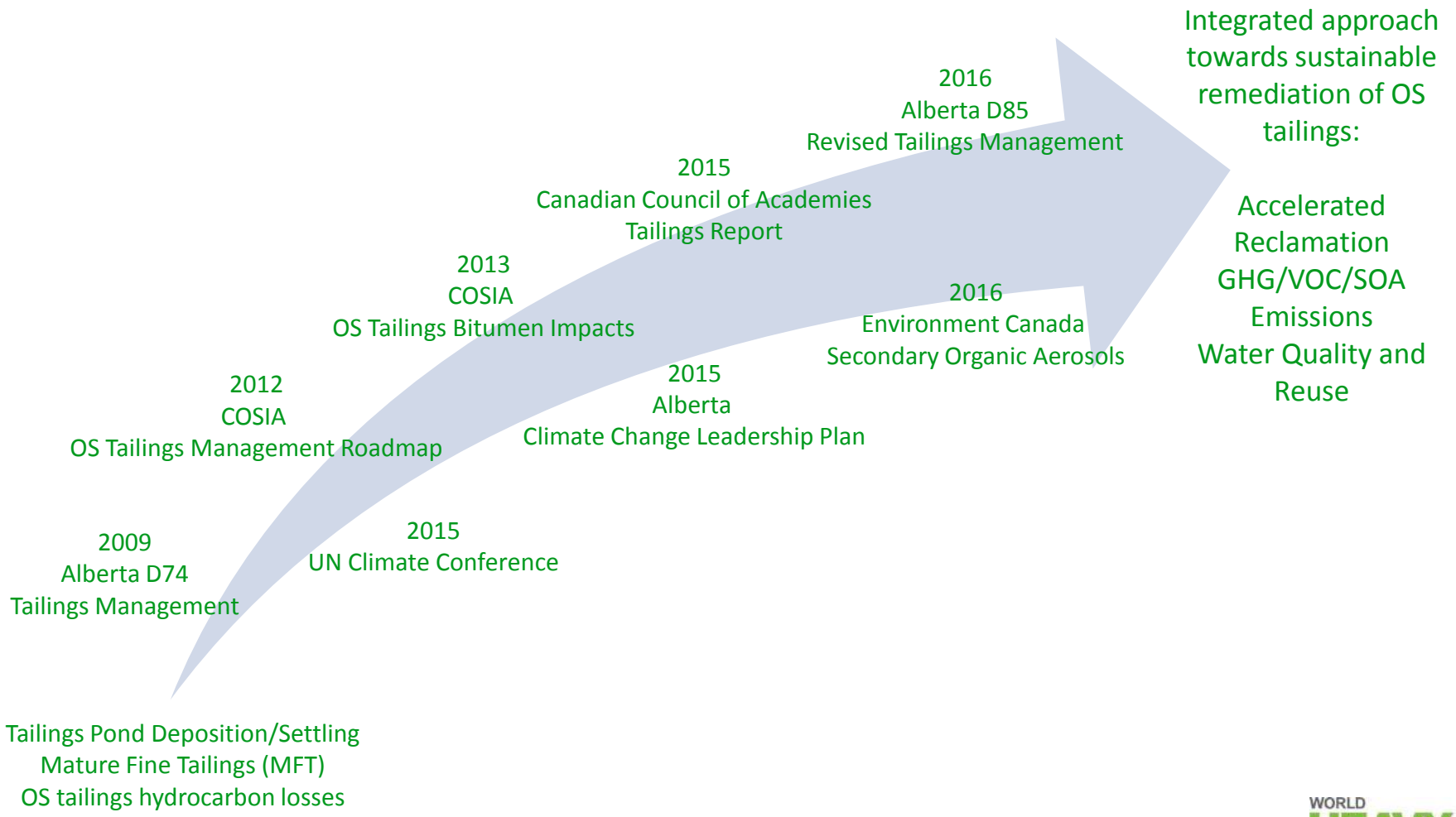
Emerging Environmental Landscape



Integrated approach towards sustainable remediation of OS tailings

2015
Alberta Climate Change Leadership Plan

Reduce methane emissions by 45% or 12 Mt/a

2015
Canadian Council of Academies
OS Tailings Report

Process 'toxic' froth treatment tailings separately

2016
Alberta Energy Regulator
Directive 85

"Ready to Reclaim" tailings deposition

Minimize environmental effect of deposition…froth treatment tailings, gas emissions…

Newell, E., S. Vaughn, M. Aubertin, J. Bergerson, I.D. Gates, M.R. Gray, J.Masliyah, G. McKenna, J. Nagendran, P. Painter, J. Peace and K. Percy (2015). "Technological Prospects for Reducing the Environmental Footprint of Canadian Oil Sands", Canadian Council of Academies, 252 pp.

Fugitive GHG/methane/VOC emissions and other challenges from Oil Sands Tailings and Ponds

(Adapted from: Small et al. (2015) "Emissions from oil sands tailings ponds: Review of tailings pond parameters and emission estimates", Journal of Petroleum Science and Engineering, 127, 490-501)

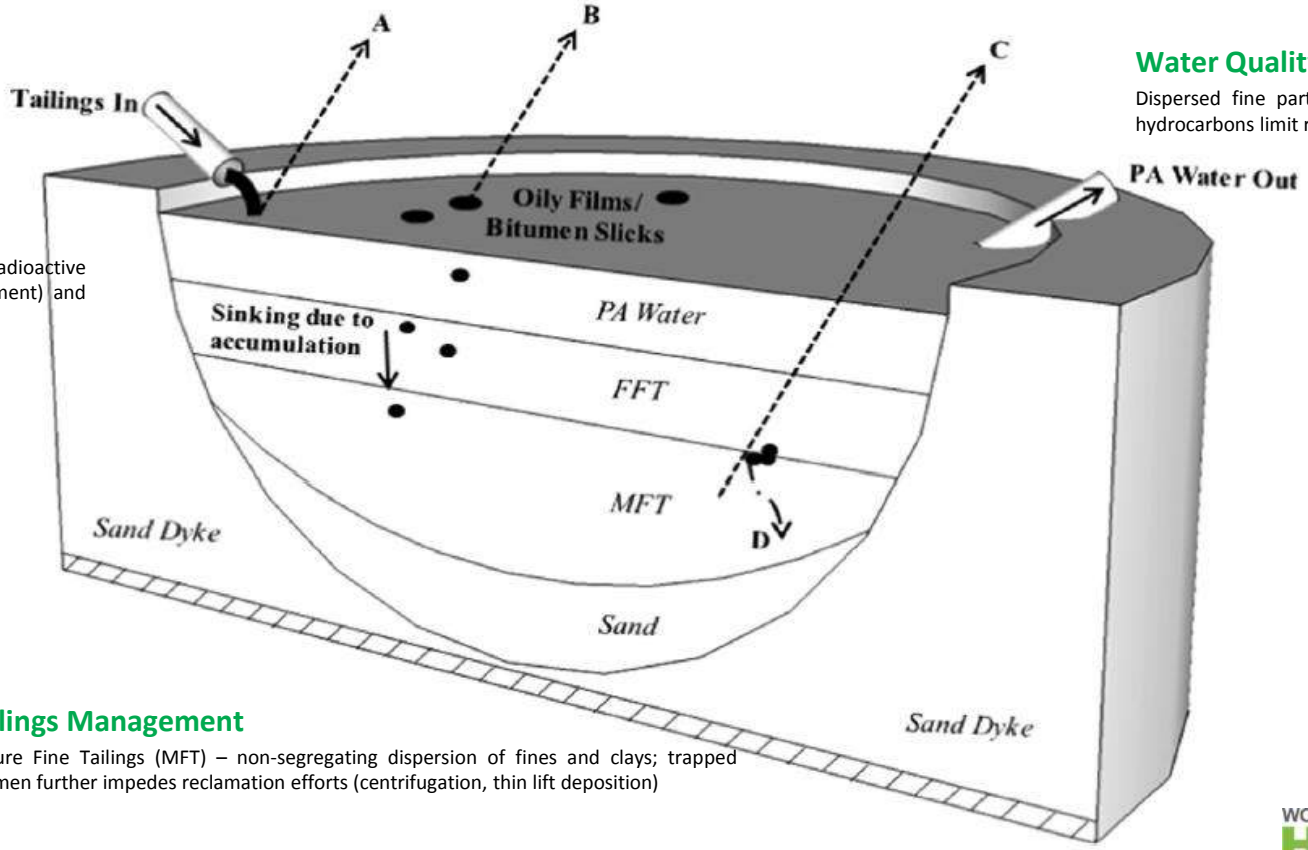
Air Emissions

A = Rapid volatization of VOCs as hot tailings solvents are discharged into the atmosphere

B = VOCs volatized from oily films at pond surface (slicks), SOA precursors

C = Anaerobic fermentation of solvents into **methane** (methanogenesis)

D = Compound cycling results in fixed carbon (bitumen/solvent) trapped in tailings



Water Quality

Dispersed fine particles and residual hydrocarbons limit reuse applications

Emerging Issues

Concentration and deposition of radioactive solids (Canadian NORM management) and pyrite (acid rock drainage)

Tailings Management

Mature Fine Tailings (MFT) – non-segregating dispersion of fines and clays; trapped bitumen further impedes reclamation efforts (centrifugation, thin lift deposition)

Titanium's CVW™ technology focuses on remediating oil sands froth treatment tailings (FTT)

solvent

Step 1: Mining

oil sands slurry

Step 2: Extraction

bitumen froth

Step 3: Froth Treatment

bitumen

- ❑ Eight oil sands individual mines
- ❑ Among the worlds largest mines
- ❑ Truck and shovel mining to 100m
- ❑ Ore contains average 10% bitumen

- ❑ 15 barrels of water used per 1 barrel of bitumen
- ❑ 85-90% of this water is recycled
- ❑ Flotation and settling processes produce bitumen froth
- ❑ Extraction tailings comprised of water, sand and bitumen

extraction tailings

froth treatment tailings

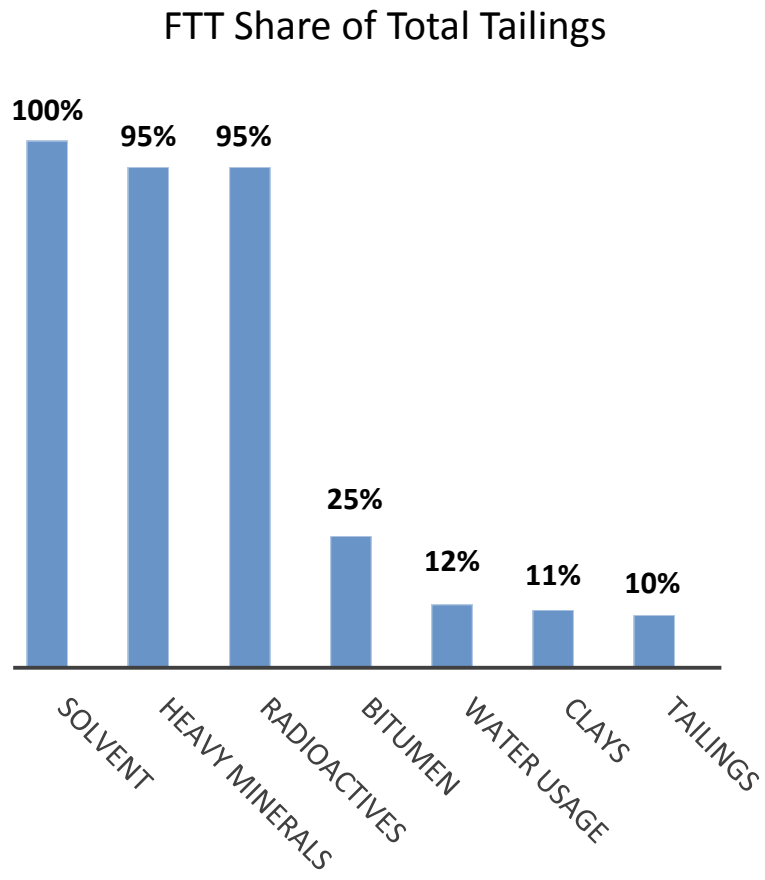
- ❑ Hydrocarbon solvent is added to bitumen froth
- ❑ Gravity separators reject sand/water
- ❑ Bitumen sent to up-graders/pipelines
- ❑ Tailings are comprised of water, bitumen, solvent and sand/fines which are discharged to ponds
- ❑ Regulations allow losses of 4 barrels of solvent per 1,000 barrels of bitumen

Tailings Ponds

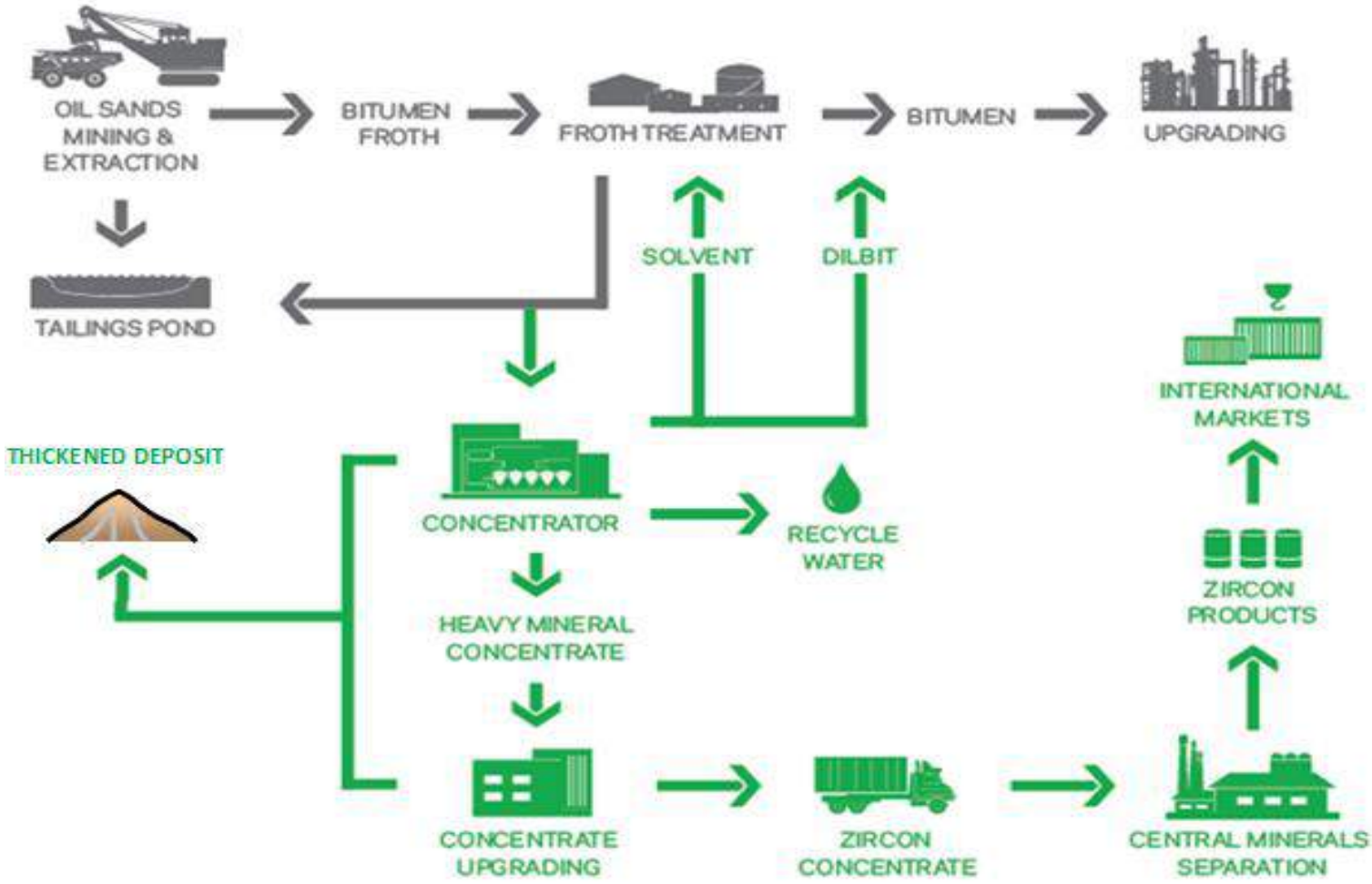
- ❑ 22 active tailings ponds, area of 220 sq km, 54,363 acres
- ❑ Tailings ponds contain 975 million m^3 of fine fluid tailings
- ❑ 90-94% from extraction tailings and 6-10% from FTT
- ❑ Largest source of fugitive GHG and VOC emissions
- ❑ Radioactive minerals from FTT are concentrated in ponds
- ❑ Process heat in FTT is dissipated to environment

Froth treatment tailings are environmentally and economically significant (although volumes are much smaller than extraction tailings)

- FTT are a mixture of water, sand, fine clays, hydrocarbons, representing 6-10% of total tailings volumes
- FTT contain most recoverable economic value
  - 100% of solvent losses
  - 95% of heavy minerals
  - 25% of bitumen losses
- FTT tailings also contain the most environmentally damaging elements
  - 100% of **methane** producing solvents, VOC and SOA source
  - 95% of radioactives



Titanium's CVW™ technology is designed to intercept FTT before discharge to ponds and recover valuable minerals, lost bitumen, solvents and water



Titanium's CVW™ is a SDTC portfolio technology, demonstrated at Natural Resources Canada's CanmetENERGY oil sands commercial pilot facilities in Devon, Alberta with the support of government and a consortium of oil sands firms

Natural Resources Canada | Ressources naturelles Canada

CanmetÉNERGIE

SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA™

- 2010-2013 integrated demo
- Industry-standard scale
- Validated by stakeholders
- 13 patents in IP portfolio

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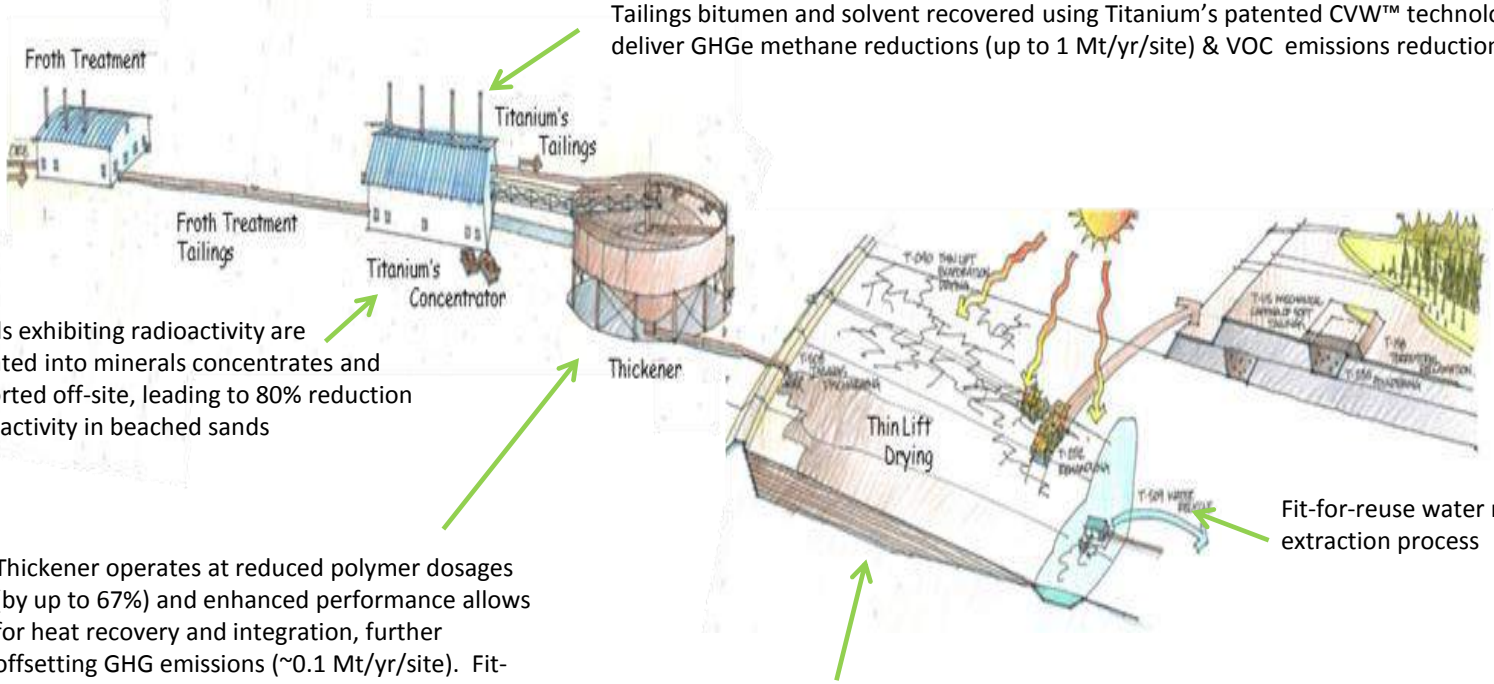
Titanium's CVW™ end-to-end tailings solution for froth treatment tailings offers potential to avoid tailings ponds completely, improving tailings management and reducing costs

Tailings bitumen and solvent recovered using Titanium's patented CVW™ technologies, deliver GHGe methane reductions (up to 1 Mt/yr/site) & VOC emissions reductions (10kt/yr/site)



Minerals exhibiting radioactivity are segregated into minerals concentrates and transported off-site, leading to 80% reduction in radioactivity in beached sands

Fit-for-reuse water recycled to extraction process

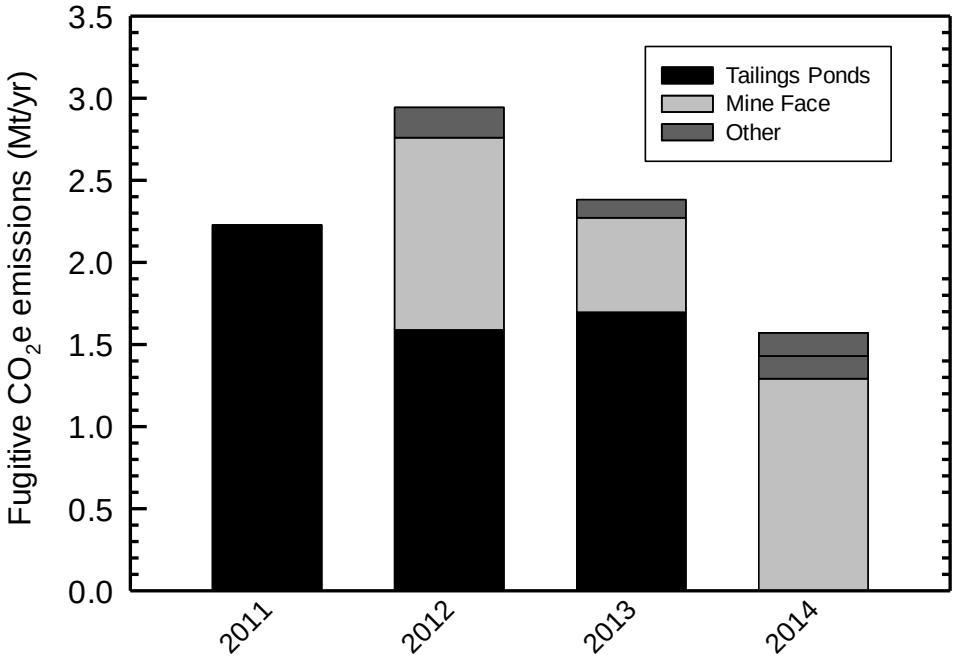
Thickener operates at reduced polymer dosages (by up to 67%) and enhanced performance allows for heat recovery and integration, further offsetting GHG emissions (~0.1 Mt/yr/site). Fit-for-reuse water recycled to process applications and/or low grade utility purposes to offset fresh water intake from Athabasca River

Tailings dewater efficiently to exceed 5 kPa strength in less than 1 year; accelerate trafficability and reduce fines loading to tailings pond

A conceptual layout of Titanium's froth treatment tailings management operations using standard industry technologies for thickening and drying (which could include other proven technologies) is shown above adapted from: Sobkowicz, J.(2012), "Oil Sands Tailings Technology Deployment Roadmaps: Project Report – Volume 1, Project Summary, Report to Alberta Innovates – Energy and Environment Solutions", File 17-235-22, Thurber Engineering.

Fugitive GHG Emissions Sources

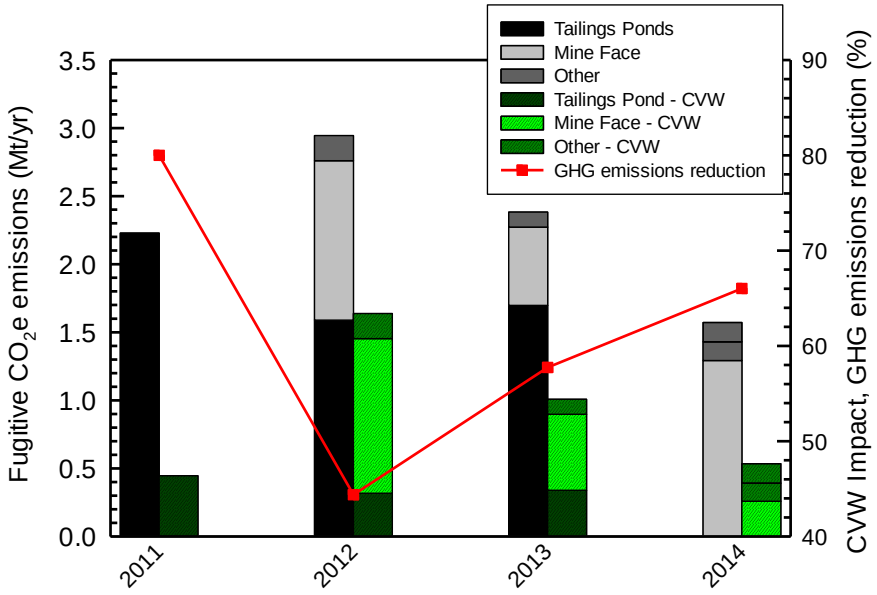
- Froth treatment tailings are the largest source of fugitive GHG emissions at oil sands site
- Tailings pond GHG emissions can represent up to 90% of fugitive losses; 10% site-wide emissions
- Tailings pond methane emissions result from microbial fermentation of FTT naphtha



"Tailings and Fugitive Emissions for SGER Oil Sands Facilities 2011-2014", http://osip.alberta.ca/library/Dataset/Details/263, Alberta Environment and Parks, October 2, 2015.

Fugitive GHG Emissions Abatement

- Titanium's CVW^{tm} removes 80% of tailings pond methane emissions; 50-70% of total fugitives
- Further abatement possible (up to 95%) as tailings directed to integrated dry reclamation deposition



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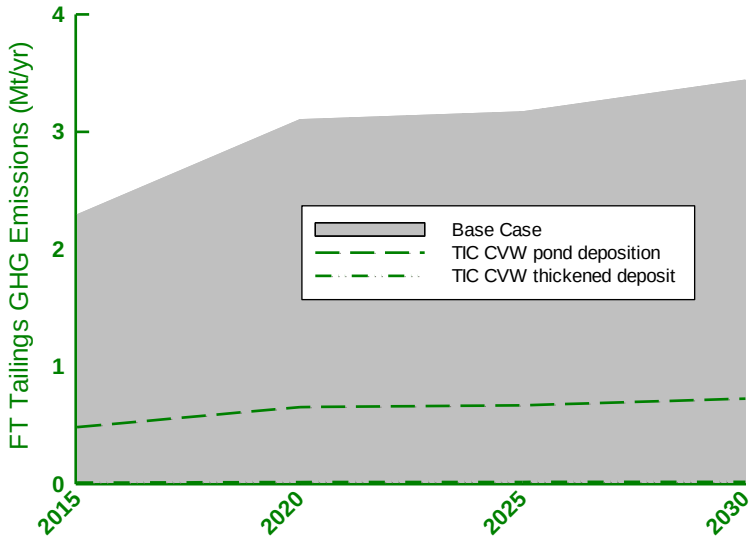

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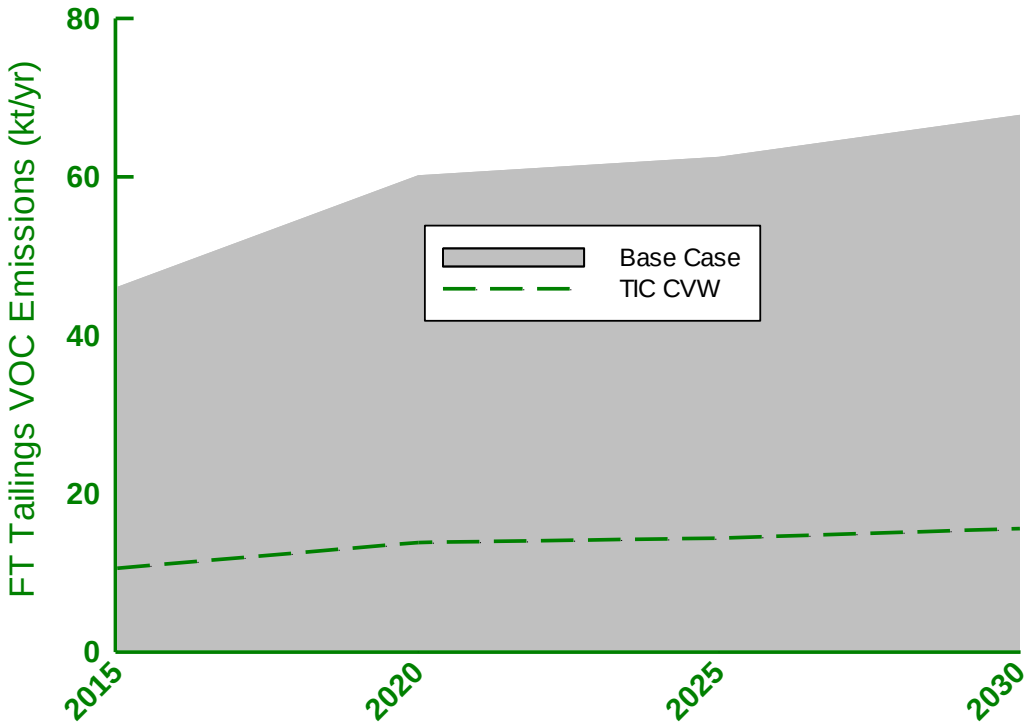
Based on mining production reported by "Crude Oil: Forecast, markets and Transportation", Canadian Association of Petroleum Producers, June 2016.

VOC and SOA abatement

- Froth treatment tailings are the largest source of fugitive VOC emissions at oil sands site
- Titanium's tailings solvent recovery technology reduces pond deposition of hot naphtha from FTT
- CVW^{tm} reduces oil sands VOC emissions by over 70% site-wide
- Recovery of semi- and intermediate volatility hydrocarbons from FTT contributes to SOA abatement

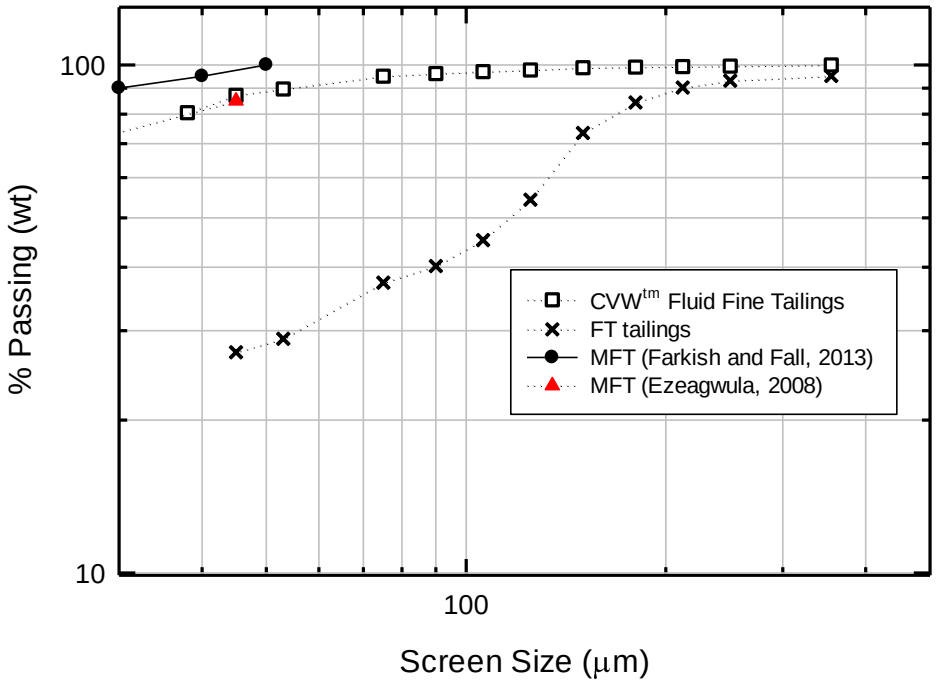


Based on VOC emissions factors reported by Dyer, S., J. Moorehouse, K. Laufenberg and R. Powell (2008). "Undermining the Environment: The Oil Sands Report Card", Pembina Institute, 59 pp.

Based on mining production reported by "Crude Oil: Forecast, markets and Transportation", Canadian Association of Petroleum Producers, June 2016.

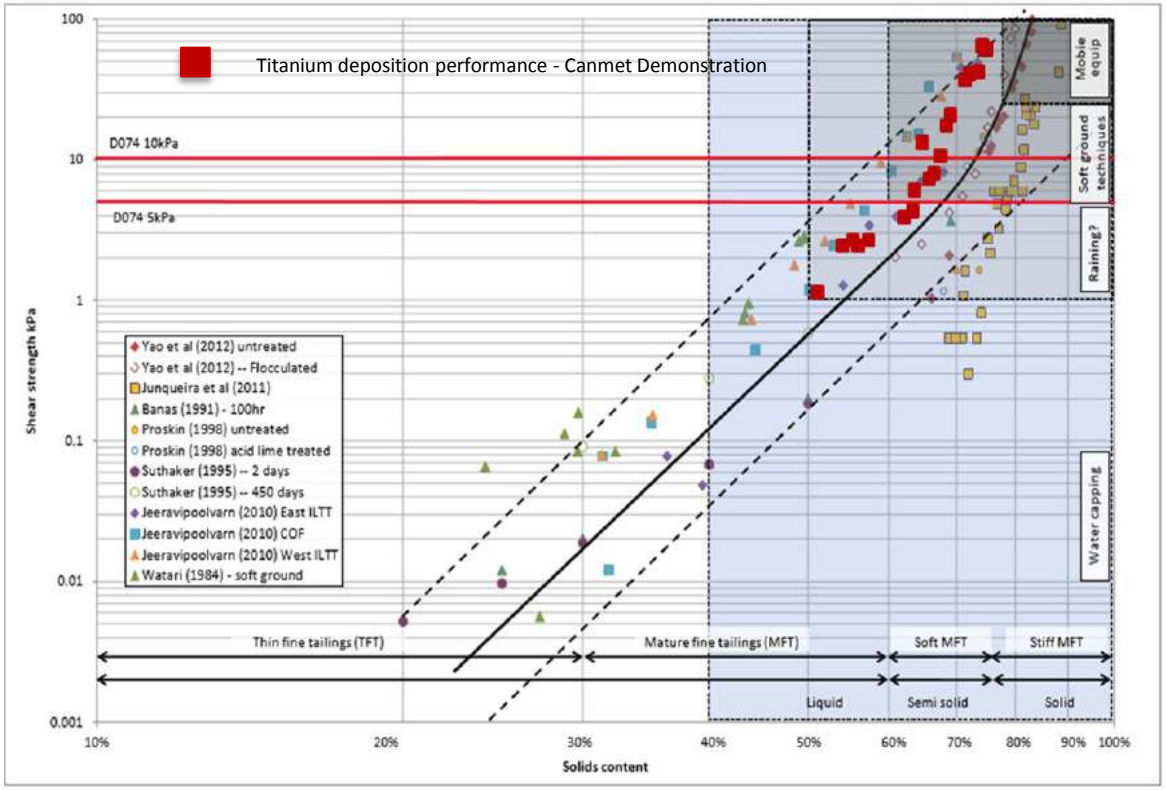
Froth Treatment Tailings Management

- Froth treatment tailings have a relatively high amount of fines material
- Further complicated by relatively high amounts of bitumen and solvent
- Titanium processing classifies solids into a fines-enriched tailings; coarse stream to HM process
- CVW efficiently recovers hydrocarbons; tailings dewatering with high fines capture



Enhanced Tailings Management

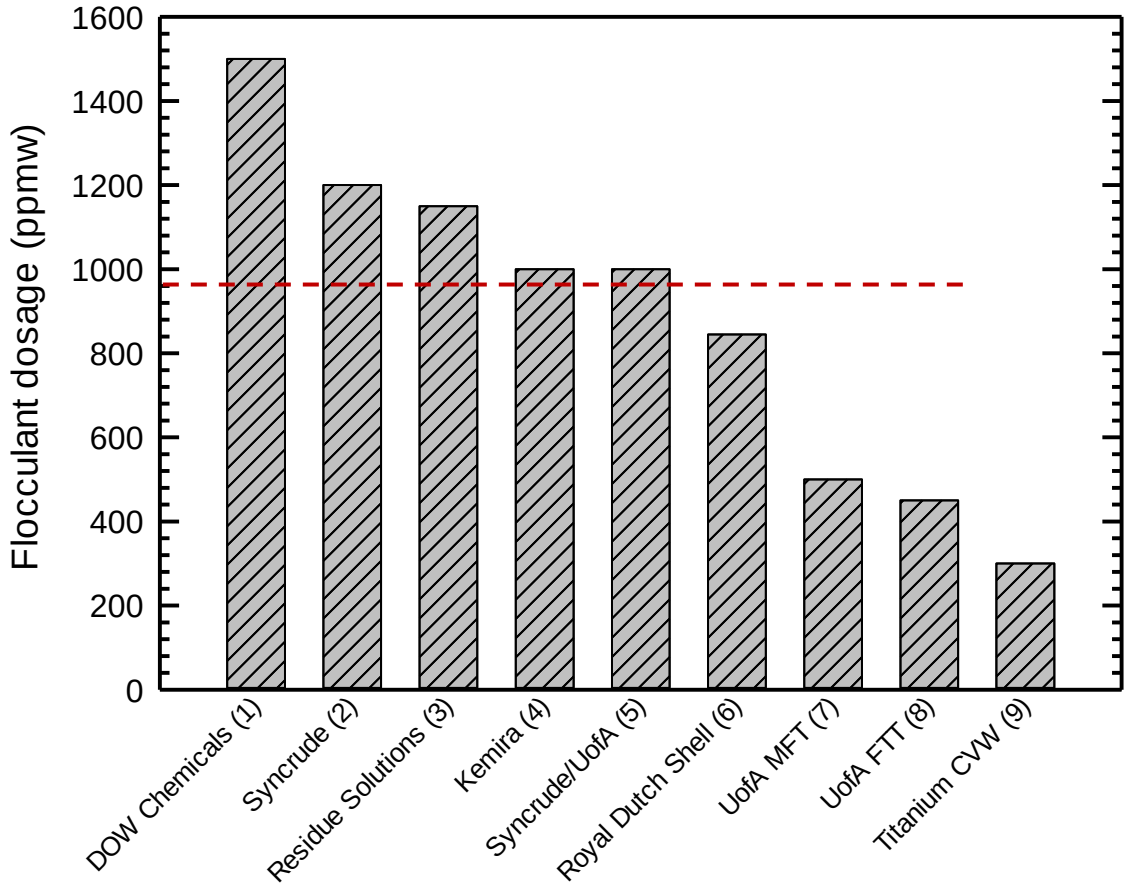
- Consolidation of contained fine solids enhanced due to low concentrations of bitumen



*Chow, R., G. McKenna, S.M.K Win and J. Journault (2013). "Recovery of Bitumen from Oil Sands Tailings Streams and Deposits: Potential Opportunities and Benefits", HOOS-16156-2013, Alberta Innovates Technology Futures; **adapted from Bromwell Engineering Inc. (1983). "Geotechnical Investigation of Mildred Lake Oil Sand Tailings Sludge Disposal, Consultants report prepared for Syncrude Canada Ltd", Lakeland, FL, pp. 119.

- Achieve solids concentrations of 75% within one year, exceeding mandated depositional strength

Consolidation at low flocculant dosage



(1) Mohler, C.E., M.K. Poindexter, J. Atias, W. Chen and C.A. Witham (2012), "Development of Flocculants for Oil Sands Tailings using High-Throughput Techniques", Third International Oil Sands Tailings Conference, Edmonton, Dow Chemical Company, 12 pp.

(2) Spence, J., B. Bara, J. Lorentz, R. Mikula, J. Lee, R.D. Lahaie, R. Cameron, R. Donahue and N. Wang (2014), "A centrifuge process for dewatering oil sands tailings", Canadian Patent 2824543, Syncrude Canada Ltd.

(3) Munro, L.D., and D. Smirk (2013), "Mud Farming of Fine Tailings – Application and Benefits of MudMaster Technology", Tailings and Mine Waste 2013, Banff, Residue Solutions, 10 pp.

(4) Fenderson, T., S.G. Thakurta, A. Mahmoudkhani, P. Watson, Y. Wu, K. Stewart (2013), "Understanding dewatering limits of polymer flocculated oil sands mature fine tailings", Tailings and Mine Waste 2013, Banff, Kemira, 15 pp.

(5) Jeeravipoolvarn, S., J.D. Scott and R. Chatalurnyk (2010). "Composite Tailings made from In-Line Thickened Oil Sands Tailings", International Oil Sands Tailings Conference, Edmonton, AB, 10 pp.

(6) Dunmola, A., N. Siddharth and R. Mahood (2013), "Shell's Atmospheric Fines Drying Technology for Dewatering Mature Fine Tailings", Tailings and Mine Waste, Banff, Royal Dutch Shell, 14 pp.

(7) Wang, X., Z. Xu and J. Masliyah (2008), "Polymer Aids for Settling and Filtration of Oil Sands Tailings", Third International Oil Sands Tailings Conference, Edmonton, University of Alberta, 31 pp.

(8) Klein, C., D. Harbottle, L. Alagha and Z. Xu (2013), "Impact of Fugitive Bitumen on Polymer-Based Flocculation of Mature Fine Tailings", Canadian Journal of Chemical Engineering, **91**(8), 1427-1432.

(9) Mikula, R., K. Dickson and J. Elias (2010). "Dewatering Treatment Options for Titanium Corporation Naphtha Froth Treatment Tailings", CanmetENERGY, 2010-092-CF, 34 pp.

- Excellent thin lift response at polymer dosing of less than 400 ppmw (vs industry avg ~1000 ppmw)

Summary

- Emerging sustainable landscape for oil sands mining – Directive 85 calls for a holistic approach to reclamation that addresses environmental performance on a number of dimensions and identifies froth treatment tailings as higher risk

- Froth treatment tailings are a significant source of environmental challenges including fugitive methane emissions, VOC and SOA emissions…

- Titanium's integrated CVW^{tm} process offers an end-to-end tailings management solution that can avoid pond deposition, abates air emissions issues and improves water usage efficiency

- CVW^{tm} has positive economics: Recovered bitumen and solvent of sufficient quality for SCO feedstock; valuable heavy minerals suitable for global markets