COSIA CHALLENGE

Mobilizing the world's minds and resources to improve environmental performance.

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Soft Tailings Capping Technology

SOLUTION DESCRIPTION: COSIA members are seeking robust, cost-efficient solutions to stabilize, cap and reclaim fines-dominated tailings deposits more than 10 metres deep that originate from treated fluid fine tailings applications. These deposits typically exhibit low load bearing strength.	**CHALLENGE SPONSOR:** COSIA's Tailings EPA is sponsoring this challenge. The Tailings EPA is seeking solutions to transform tailings from waste into a substrate that speeds land and water reclamation, without causing negative environmental impacts in other areas. *COSIA has four Environmental Priority Areas (EPAs): Water, Land, Tailings, and Greenhouse Gases (GHGs).*
CREATED: September 28, 2017 All projects are evaluated and actioned as they are received.	
For more information on this COSIA Challenge please visit **www.cosia.ca**	

Canada's Oil Sands Innovation Alliance (COSIA) accelerates the pace of environmental performance improvement through collaborative action and innovation. We bring together innovators and leading thinkers from industry, government, academia and the wider public to identify and advance transformative technologies for addressing our environmental challenges.

WHAT TO SUBMIT TO COSIA

COSIA requires sufficient non-confidential, non-proprietary information to properly evaluate the technology.

Some items that will be especially important to present in your submission are:

- Concept and basic unit operations
- Technical justification for the approach (e.g. laboratory batch or continuous experiments; pilot or demo plants; process modeling; literature precedent)
- Describe quantities and qualities of utilities and consumables that are required
- Energy inputs – quantity and type(s)
- Capital and operating cost estimates if available based on described capacity targets
- 3rd party verification of your proposed technology. 3rd party verifiers should be reputable, independent engineering companies if possible
- Basis of cost estimation, including estimation scope, contingency, etc.
- IP status of your proposed technology
- What operating environment restrictions might your technology face:
  - Explosive atmospheres
  - Severe weather
  - Power fluctuations

FUNDING, FINANCIALS, AND INTELLECTUAL PROPERTY

COSIA members are committed to identifying emerging technologies and funding the development of the technologies to the point of commercialization, while protecting the Intellectual Property (IP) rights of the owner of the technology.

Successful proposals can receive funding from COSIA members to develop and demonstrate the technology in an oil sands application. Multiple technologies may be funded, at the discretion of the Members.

HOW TO SUBMIT TO COSIA

Submit a summary of your solution using COSIA's Environmental Technology Assessment Portal (E-TAP) Process, available at: http://www.cosia.ca/initiatives/etap/idea-submission-form

Please note: ETAP is a staged submission process. The initial submission requires only a brief description and limited technical information. Upon review by COSIA, additional information may be requested. Instructions for submission are provided on the ETAP site.

All information provided is non-confidential. COSIA will respond to all submissions.

DETAILED SOLUTION DESCRIPTION

The COSIA Tailings Environmental Priority Area Steering Committee (TEPA SC) is inviting proposals for robust, cost-effective "Soft Tailings Capping" technologies required to safely and efficiently convert soft fines-dominated tailings deposits more than 10m deep into stable terrestrial landforms. The capping cycle may include process steps like:

- Deposit preparation during the final stages of tailings operation, *e.g.*by addition of strength-enhancing agents, to improve the rate at which deposits will become available for capping/reclamation material placement.
- Preparation of deposit for safe access through natural processes, *e.g.* through various methods for crust formation. For illustration purposes, one can envision methods to maximize evaporative action during summer months or maximize freeze-thaw action during the winter months. Efficiency of these mechanisms could in principle be increased if the top layer of the deposit could be refreshed regularly, but personnel access to the area is generally difficult. Any 'shore-based' (*e.g.* enhanced evaporation using parabolic mirrors) or 'remote operated' (*e.g.* remote-controlled amphi-rollers) method of surface management would be considered value added in this context.
- Technology-assisted preparation of deposit for safe access, *e.g.* through the application of materials to enhance geotechnical strength. While geofabrics are a logical starting point, creative alternatives like the use of vegetation would be preferred.
- Enhancing deposit dewatering performance through improvements in management of dewatering paths. A common example of this would-be installation of vertical wick drains, but creative alternatives are encouraged.
- Small lift, even-layered material placement/spreading on soft tailings. Due to the relatively large amount of material that needs to be placed, industry has historically relied on either direct or hydraulic placement of material. Direct placement (*i.e.* trucks, dozers) require significant initial load bearing capacity of the substrate which is not available (except perhaps by means of crust formation techniques described earlier). Conversely, hydraulic placement carries the potential for eroding the deposit with the slurry runoff, and typically results in localized loading. Any technology that can practically provide approximately 10 cm lifts over the cross-section of a tailings deposit without inducing surface failures would be considered an extension to the available toolkit.

It should be noted that the examples above are provided for illustration purposes only. The TEPA SC is explicitly looking for creative alternatives that may be outside conventional oil sands mining practices.

Successful technologies will safely and cost-efficiently aid with:

- Deposit preparation for access, potentially by means of remote operation
- Dewatering performance improvement
- Material placement
- Instrumentation/monitoring/modeling of the above

It should be noted that potential impact of the proposed technologies on the land, water and greenhouse gas emissions will be considered in the technology evaluation. Detailed material properties for fines dominated deposits created by flocculation, flocculation/centrifugation or via thickeners are provided in Appendix 1.

Fines dominated materials are contained in some form of fluid containment structure. The dimensions for these structures are in practice highly dependent on the details of the ore body and mine/tailings plan. For this exercise, consider fines dominated deposits placed in three structures:

- One structure with a size of 2 km by 2 km by 50 m depth. Typical fill time for such a structure would be 10 to 15 years.
- One structure with a size of 1 km by 1 km by 25 m depth. Typical fill time for such a structure would be 1 to 2 years.
- One small structure of 0.5 km by 0.5 km by 10 m depth. This could be considered a residual MFT area that is left over after the majority of the material in a pond is converted.

The TEPA SC is looking forward to proposals that frame potential technology options that can contribute to converting such soft fines-dominated deposits into a terrestrial landform in a timeframe of up to 10 years. Proposals should capture minimum input (*i.e.* starting point) requirements for the technology, as well as a definition of the 'end state' delivered by the technology (*e.g.* minimum anticipated load bearing capacity post technology deployment, maximum residual settlement expected post technology deployment).

In addition to the technology option, the technology community is encouraged to provide thoughts on preferred scale of deployment, as well as a high-level cost profile for deployment. It should be noted that based on aspects like level of detail, probability of success, level of innovation and the extent to which capping would be achieved, resources could be made available to further assist with cost estimating.

BACKGROUND

Surface mined oil sands operations are currently restricted to the Cretaceous McMurray formation in the Athabasca oil sands deposit of Northern Alberta, Canada.

Bitumen in oil sands is biodegraded resulting in a very low API gravity, typically 8°. Bitumen content in the formation is quite variable but the mineable range is between 6 and 18 wt%. Mined oil sands contain up to 5 wt% connate water and 80 – 85 wt% mineral solids. Greater than 75 wt% of the mineral solids is coarse sand (size fraction larger than 44 µm) and the fine mineral component (size fraction less than 44 µm) is largely silt sized.

The clay mineral fraction (defined as material smaller than 2µm), which dominates the behaviour of fluid fine tailings are primarily kaolinite and illite, with significant amounts of mixed layer illite-smectite and kaolinite-smectite and minor to trace concentrations of chlorite and smectite. To extract bitumen from oil sands, up to 1 m^3 of warm water per tonne of ore is mixed in hydrotransport lines to liberate bitumen from minerals.

The bitumen is recovered in a froth layer in a primary separation vessel and flotation cells, while the bulk of the minerals is recovered in a fine and coarse tailings stream, which are often combined into a whole tailings stream. A small fraction of the mineral solids report to the bitumen froth and is recovered during secondary processing to further purify the bitumen. This mineral stream reports as froth treatment tailings and is often separated from the primary extraction tailings stream.

In conventional tailings deposition and dike cell construction, tailings slurry (whole tailings or cyclone underflow) is pipelined and discharged onto the beaches inside the dike or discharged into cells where dozers compact the material to form dikes. Upon discharge, the tailings slurry segregates such that the coarse sand material drops out near the discharge location and the release water runs down the beach to a pond taking the fine-grained particles with it. The fines-water mixture, often about 10 wt% solids, reports to the pond at the end of the beach, is commonly referred to as thin fine tailings (TFT). After a short time, the TFT settles to a somewhat denser state, about 30 % solids by mass, and is referred to as mature fine tailings (MFT). TFT and MFT are both considered to be fluid tailings (FT). Over 80 per cent of the water used in the extraction process (oil sands process water or OSPW) is recycled from the release water in the tailings ponds.

Both sand and fines-dominated deposits are expected to be capped in some manner. Caps may be used to provide separation between underlying tailings materials and overlying reclamation materials, accelerate consolidation of the tailings, serve a beneficial role as part of the reclamation substrate and facilitate physical access to the deposits for the purpose of placing reclamation materials.

While members have successful commercial-scale experience in capping sand-dominated deposits, there has been limited experience with capping of soft, fines-dominated tailings materials placed in relatively thick deposits which are subject to substantial post-placement settlement and associated water release. To date, fines-dominated deposits have been created commercially using thickeners, centrifugation and inline flocculation.

APPROACHES NOT OF INTEREST

- Capping of sand-dominated deposits as these have already been successfully capped at commercial scale.
- The TEPA SC is explicitly *not* interested in technologies that are directly tied to the bitumen extraction process. While tailings sand can be made available for reclamation technologies, the technology provided cannot rely on the bitumen production facility to deliver that sand to the capping area.
- Sand, water, diesel fuel and power can be considered available to the technology. All other materials will need to be supplied from outside sources. Should any specialty chemicals be proposed, then both cost and logistics/supply chain considerations for full commercial deployment as well as additional environmental exposure as a result of the chemistry will need to be acceptable.

Appendix 1

Acronym	Name	Material Description	Genesis	Other Names used in literature.	Sources	Solids Content (mass solids/mass total)	SFR (mass sand/mass fines)	Fines Content (<44um, mass of fines/mass solids)	Clay Content (<2um, mass clay/mass solids)	Bitumen Content (mass bitumen/mass total)	Dry Density (kg/m3)	Liquid Limit (based on geotechnical moisture content)	Plastic Limit (basedon geotechnical moisture content)	Peak Undrained Shear Strength (Pa)	Yield Strength (Pa)	Viscosity (mPa.s)
TT	Thickened Tailings	Flocculated fluid suspension of oil sands fines that is typically either very high fines (>90%) or a mixtyre of fines with sand (typically 50% fiens). In shallow lift deposits, it rapidly consolodates and may crust (see dMFT below). In deep deposits, it consolidates slowly to form a low strength soil-like material. TT has a wide range of properties: it may be deposited as a very low density slurry (say 20% solids), a moderately low density slurry (40% solids), as a medium density slurry (45-55% solids) or as a high density paste (>55% solids) that has very little bleedwater. Consistency: similar to that of chocolate milk to pudding to pie-filling (with larger flocs)	A high fines tailings stream (perhaps diluted with water or amended with sand) is flocculated with a polymer mix. The slurry may be densified in a thickener vessel to produce thickened tails (TT) or paste tailings (PT) (if approaching the liquid limit) or in-line (ILTT) which produces no densification prior to discharge. The flocculated structure allows more rapid consolidation that that provided by FFT. The discharged slurry forms a subaerial or subaqueous beach that consolidate/densify over time.	Thickened tailings (TT) Past tailings (PT) In-line thickened tailings (ILTT) In-line flocculated tailings (ILFT) Flocculated tailings (FT)	Tech Guide (2012), IOL Kearl TT Studies; Golder (2013-2014), Shell TT pilot: Barr(2015), Total TT pilot (2014), industry experience.	30% to 70%. 40-45% is common range. Early dewatering 50% to 65%. 30%-60% for TT, 40%-50%(typical), for PT-TT, 50%-75%, 60%(typical)	0.2 to 1.5; as high as 3.<1(typical). 0.5-3;most like 0.8-1.5 after adding FFT, 2(typical w/o FFT), 1(with FFT)	40% to 80%. 60% (typical) 25% to 66%. 33%(typical)	5% to 35%. 20%(typical) 10% to 40%, 25-35%(typical)	0.3% to 3% (0.1% to 2%)	1200 to 1700. 1500(typical) 1230(30%SC) to 1600(60%SC), 1389 (typical, 45%)	25% to 50%. 30%(typical)	10% to 20%, as high as 25%. 15%(typical)	PT-TT:500-2000Pa, 1000Pa(typical)	2 to 80 common range. Increases quickly w/SC increase. 100s to 1000 within days of deposition. TT: 0-120Pa, 15-60Pa(typical)	200 to 1000. Increases with time. 100-5000 cp.
ADW	Accelerated Dewatered Tailings	Flocculated high fines material which slowly consolidates in deep deposits, forming a low strength material (see TT and dMFT)	A high fines tailings stream is flocculated with a polymer mix, typically in-line. The slurry is discharged in a deep deposit (often 30-50m) and form a subaerial or subaqueous beach that consolidates over time. Note, ADW does not involve thickeners (TT), centrifuges (CFT) or thin lift deposition with drying (dMFT)	Accelerated Dewatered Tailings (ADW) In-Line Flocculated tailings (ILFT)	Tech Guide (2012), Syncrude Papers (2010, 2011), Suncor Paper (2011), Shell TD (2011), Industry experience.	MFT 30%-40% common range. 35%(typical) Early dewatering 40% to 50%	MFT <1. 0.25 to 0.75 common range.	MFT 60% to 97% common range. Average 85%(typical)	MFT 5% to 40% common range. Average 25% (typical)	MFT 2% to 10% common range. As high as 25%. Average 5% (typical)	Slightly lower than MFT due to floculant solution addition.	60% to 100%. 60% to 70% common range. Average 22% (typical)	20% to 40%. 20% to 25% common range. Average 22% (typical)	300 to 2500. Depends on SC; lower near 40%, higher near 50%.	50 to 600 common range. 150(typical). Increases w/SC increase.	
CFT	Centrifuged Fine Tailings	Flocculated homogeneous high fines slurry. If not sheared, it has a semi-solid very true texture. In deep deposits, it consolidated very slowly to form a low strength soil-like material. Consistency: similar to a still pudding (if unsheared) or smooth milkshake (if sheared).	The FFT dredged from the tailings pond. A flocculant and/or polymer is added and the slurry fed into a scroll centrifuge that spins the water out as centrate and produces a mud cake which is then pumped to a deposit for beaching.	CT: Centrifuged tailings cMFT: centrifuged mature fine tailings cFFT: centrifuged fluid fine tailings CP: centrifuge product cake, centrifuged cake	Tech Guide (2012), Syncrude Research (2010), Teck experience	MFT. 30%-45% common range. 40% (typical) 40% to 60% early dewatering. 50% (typical) for cake.	MFT <1. 0.25 to 0.75 common range.	MFT 60% to 97% common range. Average 90%(typical) in this study.	MFT 5% to 40% common range. Average 25% (typical)	MFT 2% to 10% common range. <5% in this study; 2.5% (typical)		55% to 70%. Average 65% (typical)	20% to 25%. Average 22% (typical)	1500 to 3500 at 1 month (54% to 63% SC). 4000 to 8000 with time (60% to 68% SC)	500-2000(1200 typical)	

SOURCE: *Fine Particle Resuspension Suppression Using Chemical Treatment and Capping – Literature Search and Body of Knowledge Capture.* December 2016