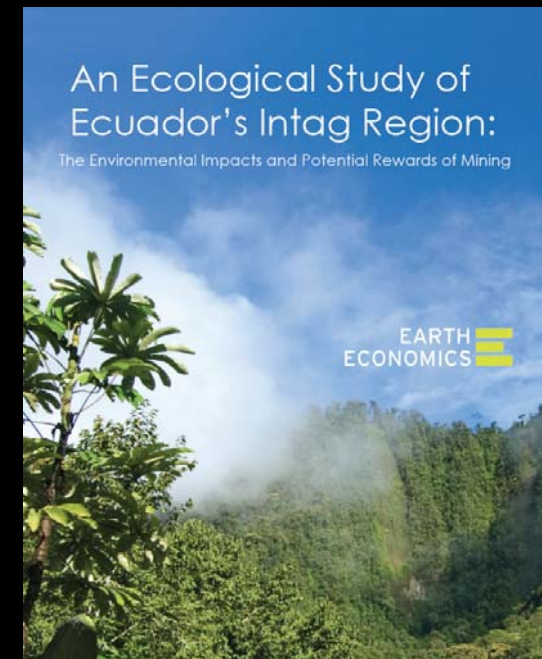
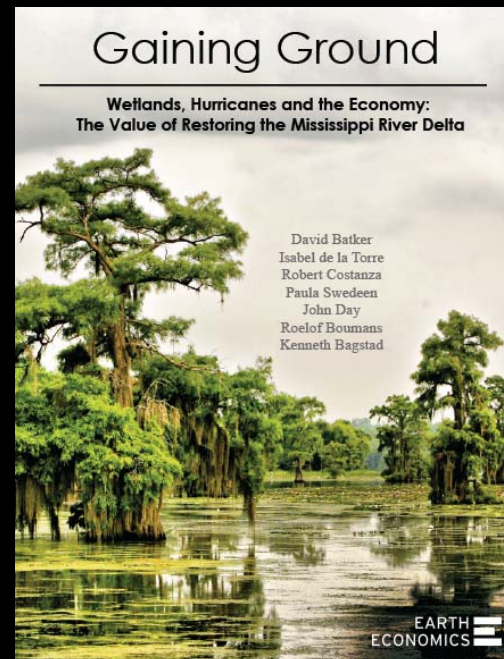
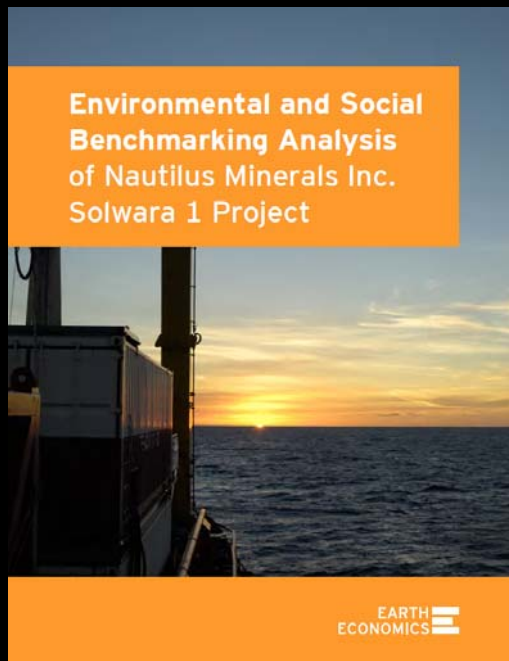


Environmental Impacts of Offshore Mining Compared to Conventional Land Mining

David Batker

Earth Economics Executive Director

November 28, 2016



The Environmental Impacts of Terrestrial Mining are Costly and Rising



2015 Samarco Iron Ore Mine Tailings Spill in Brazil



© DW/N. Pontes



Holden Mine Tailings, \$200 million in 2015

Photo: Rio Tinto

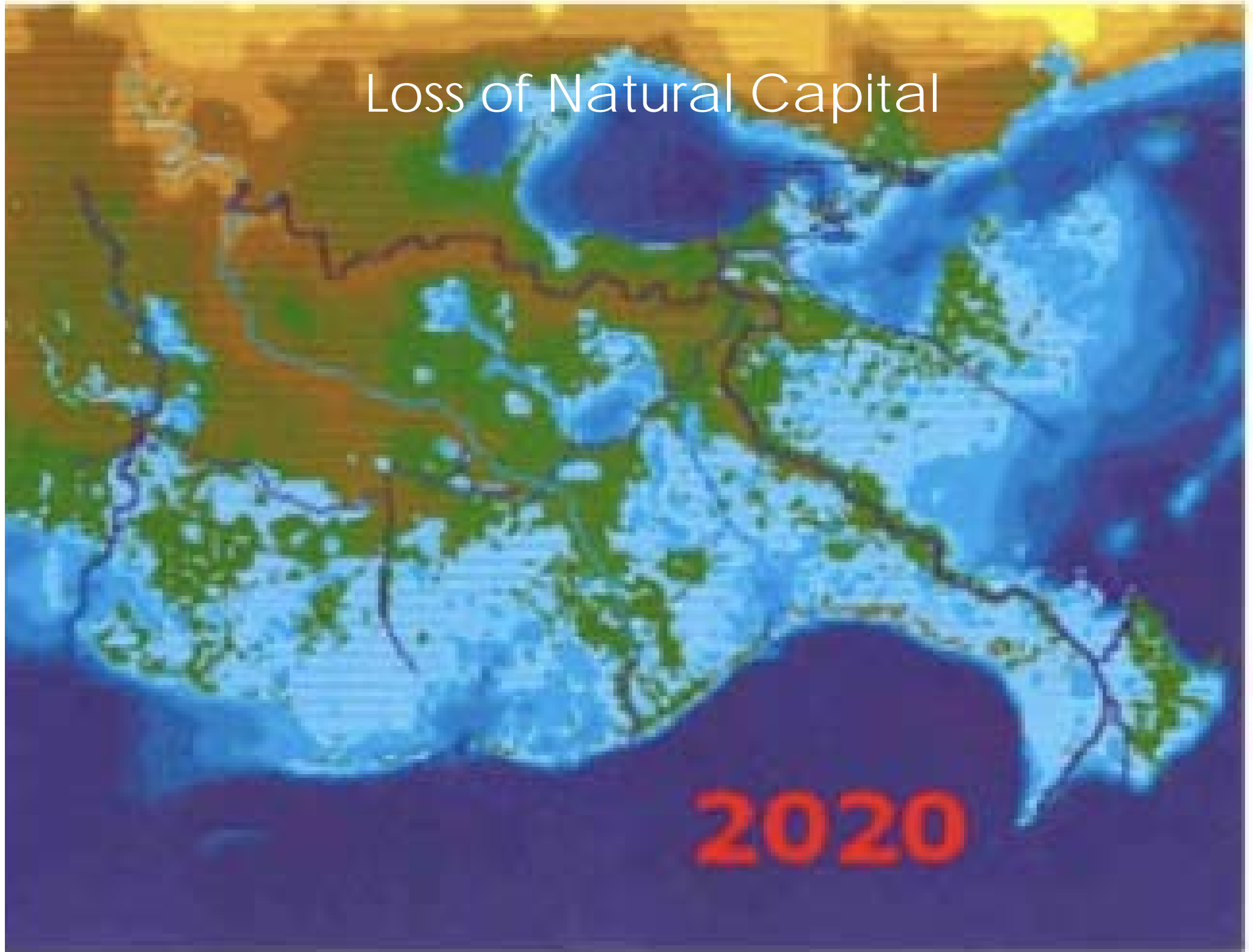
Gravity is a tough,
persistent opponent





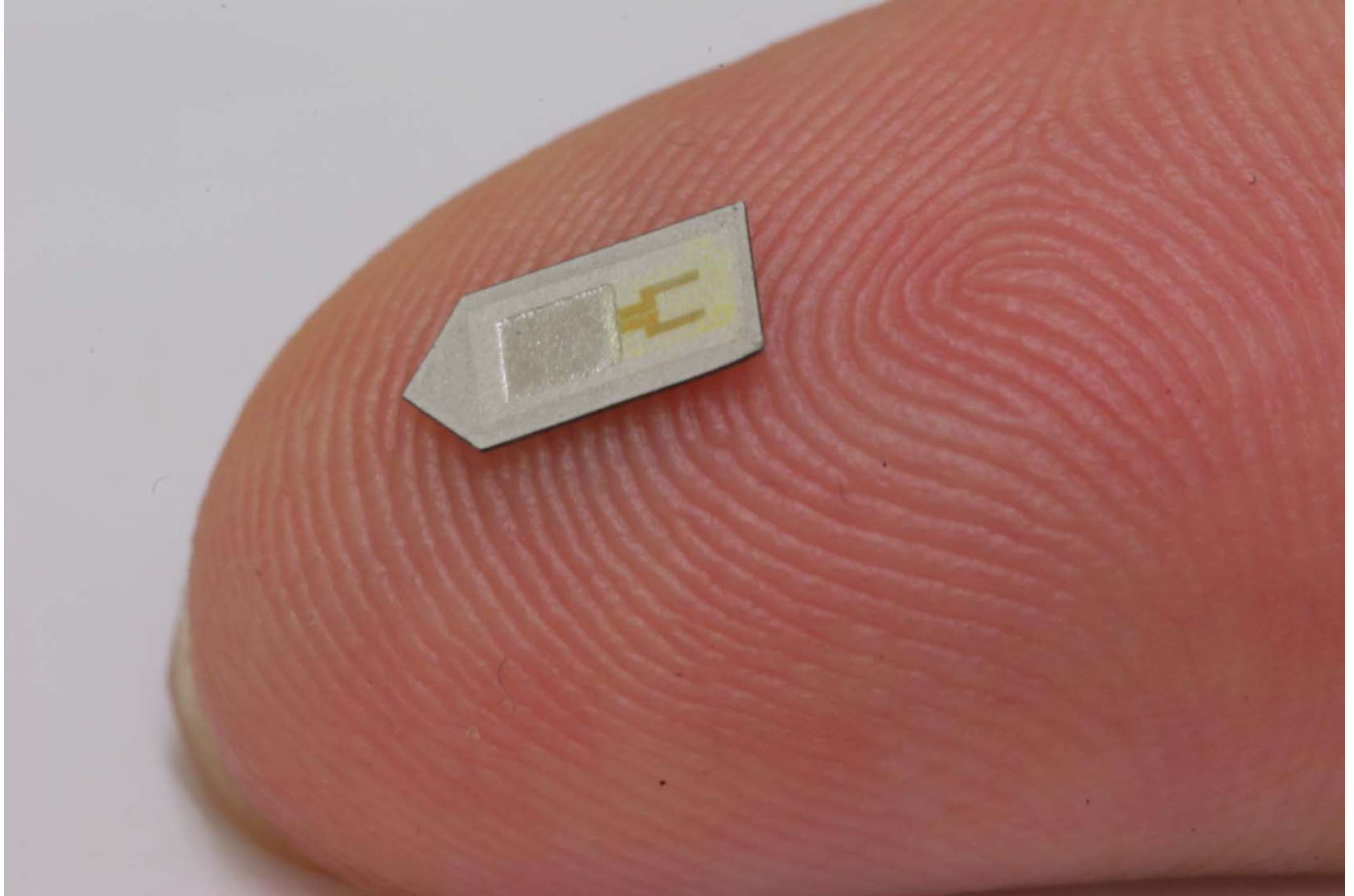
Loss of Natural Capital

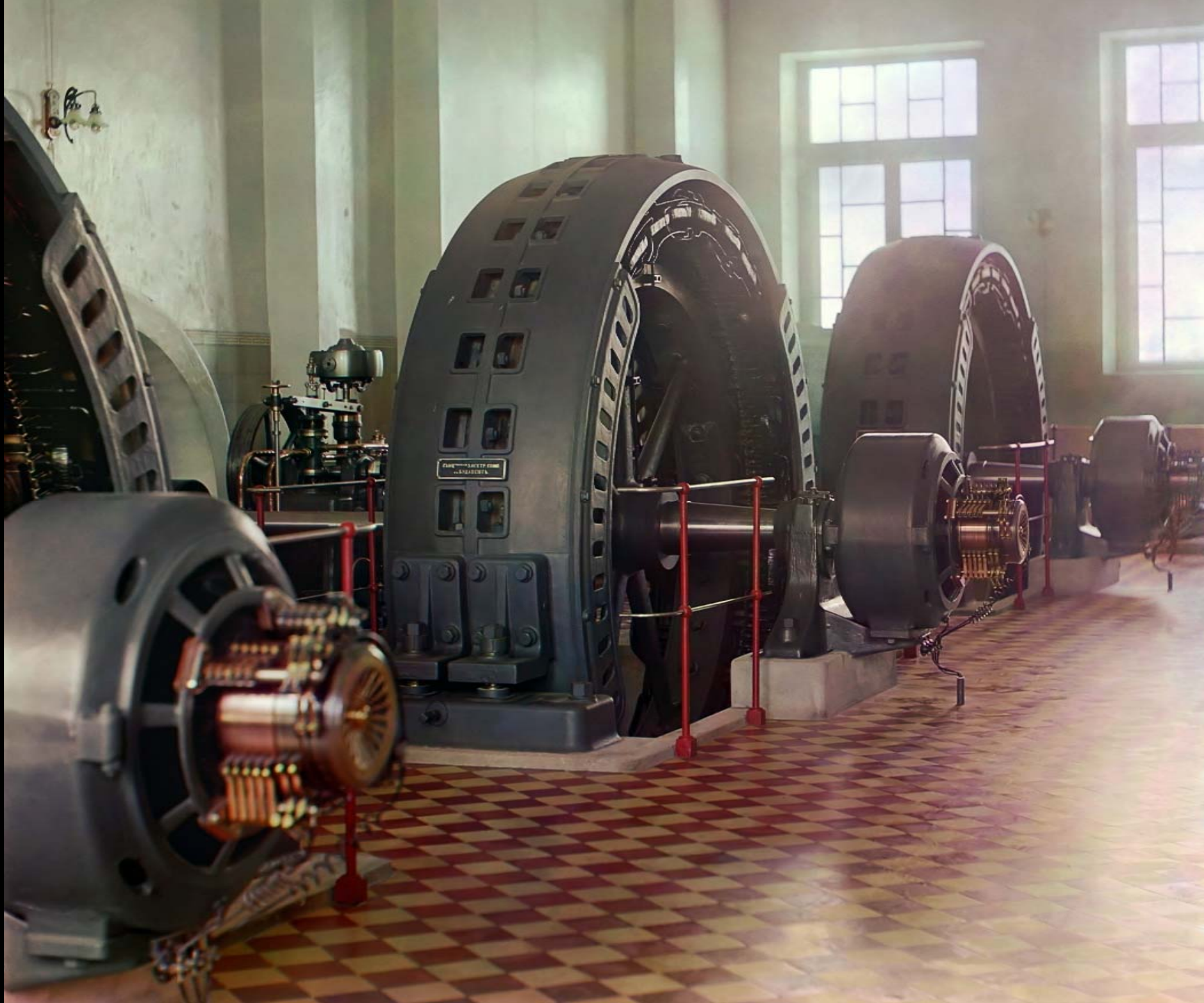
2020



How do we measure the environmental and social impacts of mining?



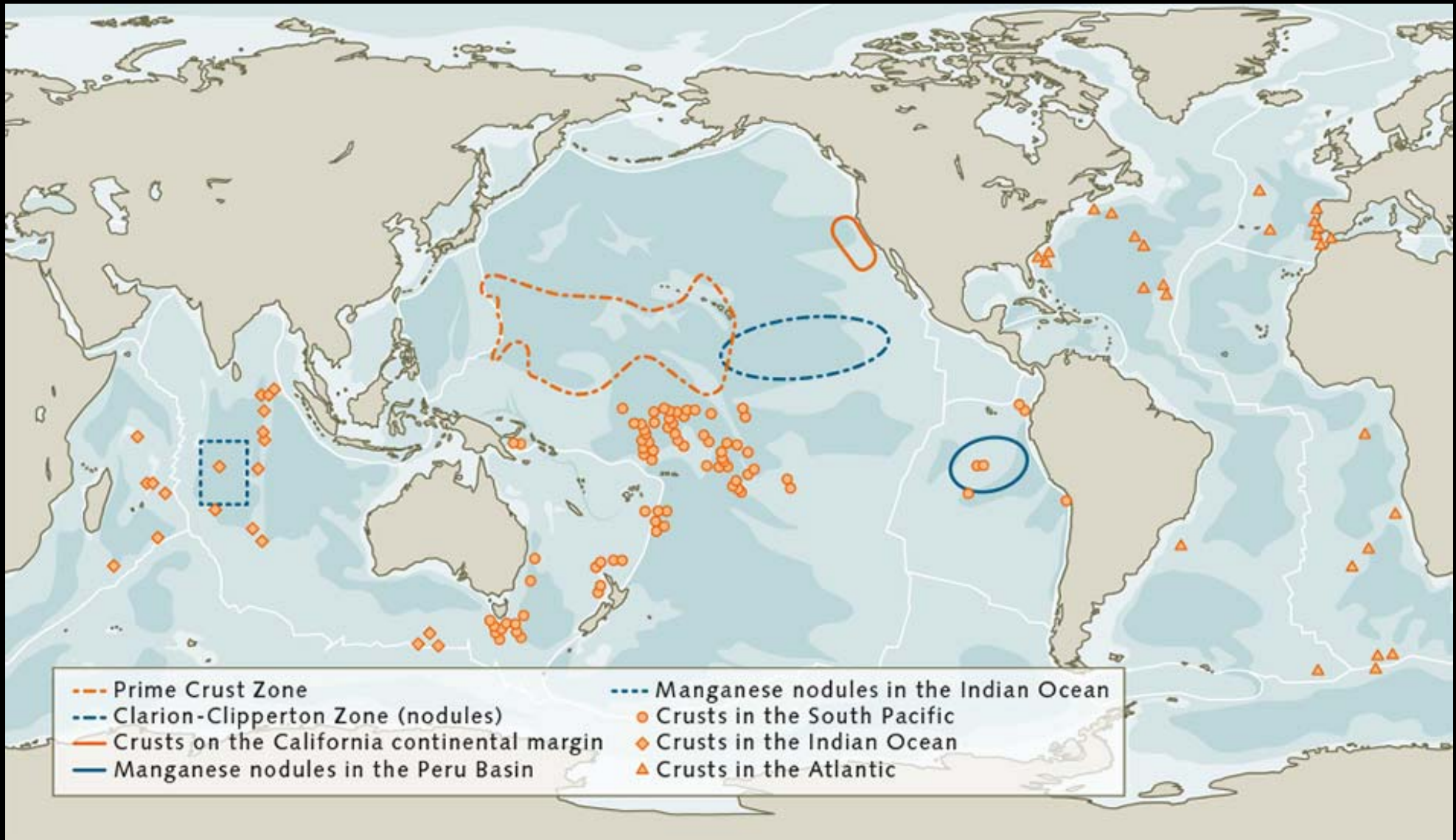




Cobalt Mining and Child Labor



Cobalt and Other Metal Rich Crusts

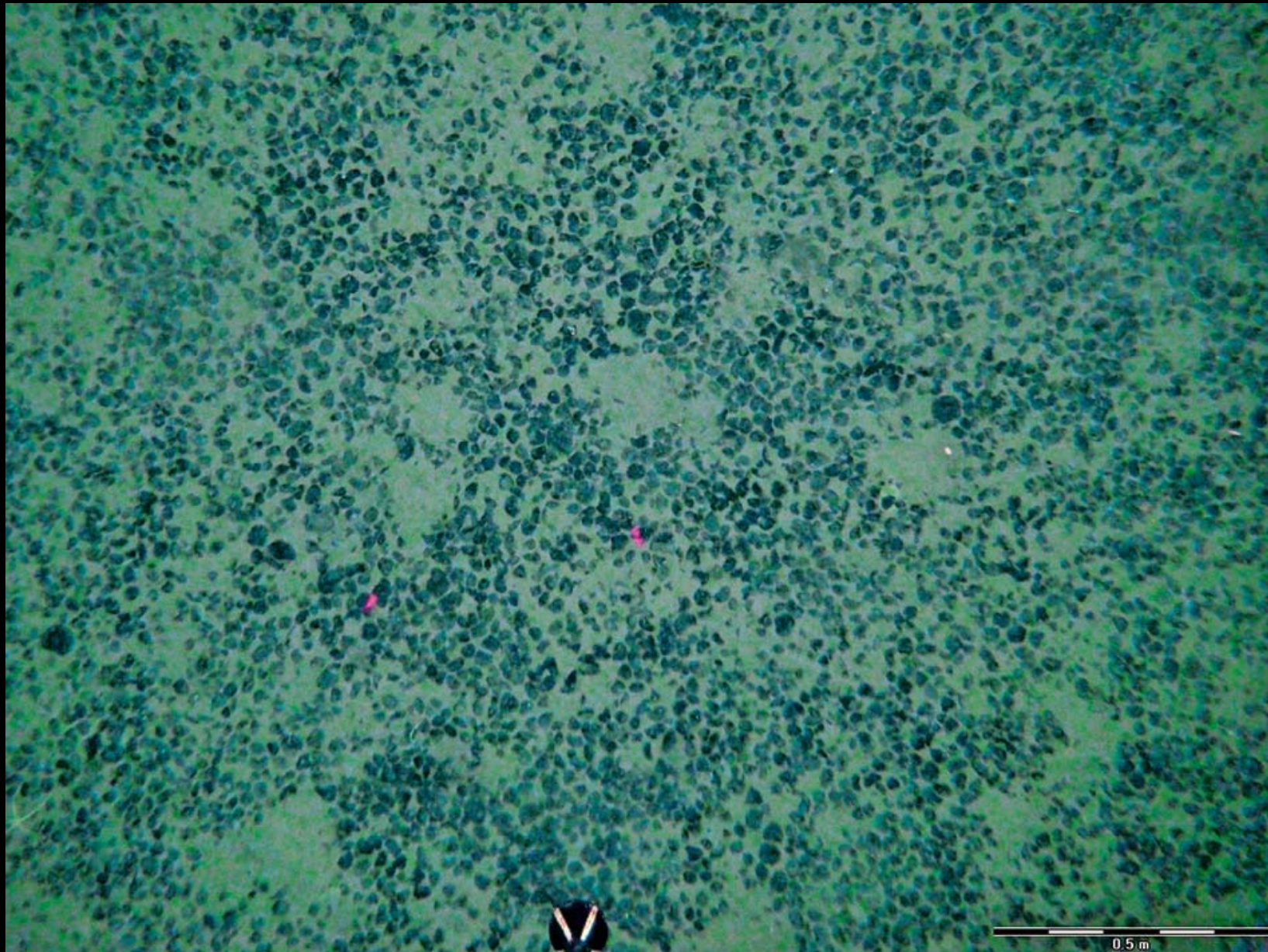


World Ocean Review

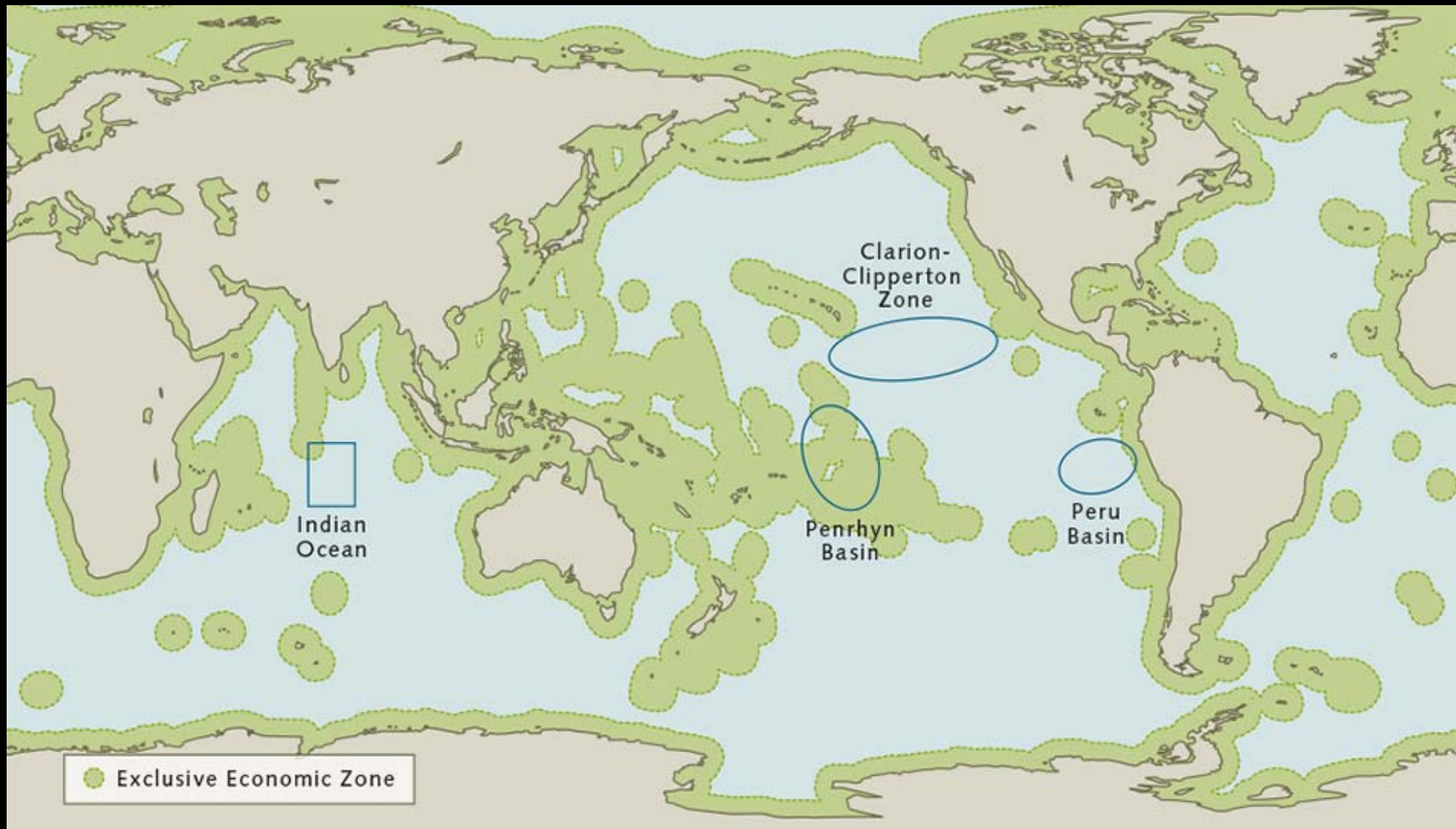
Mamatwan Manganese Mine, South Africa



Polymetallic Nodules



Four areas of greatest interest for nodules



Seafloor Massive Sulfides



North Su, active subsea volcano

Framework for Evaluating Mining

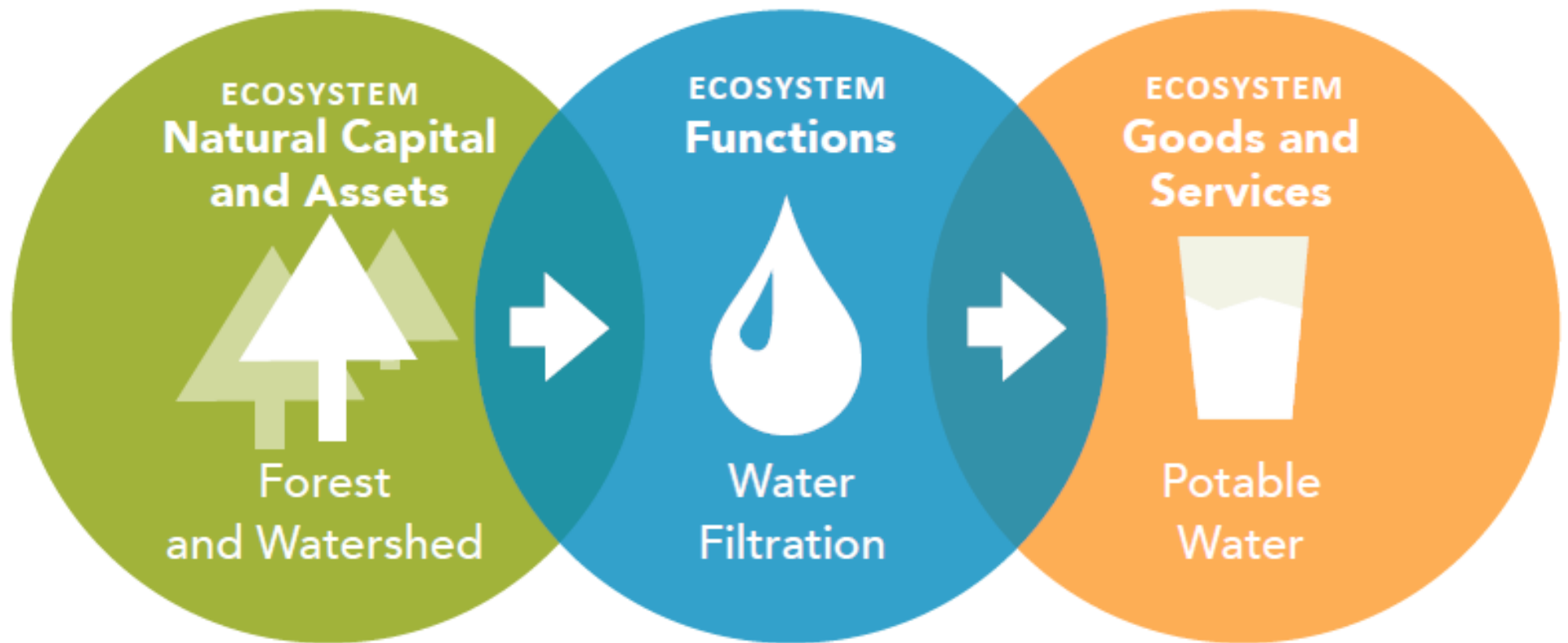
Who's Interested?
Investors, Lenders, Insurers,
Reinsurers, Guarantors



Uniting Environmental and Financial Analysis



Natural Capital and Ecosystem Services





Food Production





Goods

Food

Water Supply

Minerals

Medicine

Fiber

Fuel

Carbon



Services

Flood Risk Reduction

Gas & Climate Stability

Water Quality

Fire Risk Reduction

Soil Erosion Control

Sediment Transport

Natural Pest and Disease Control

Soil Formation

Water Flow and Temperature Regulation



Supporting Functions

Pollination

Biodiversity and Habitat

Nutrient Cycling

Net Primary Production



Cultural Functions

Aesthetic

Recreation

Cultural Values

Spiritual & historic

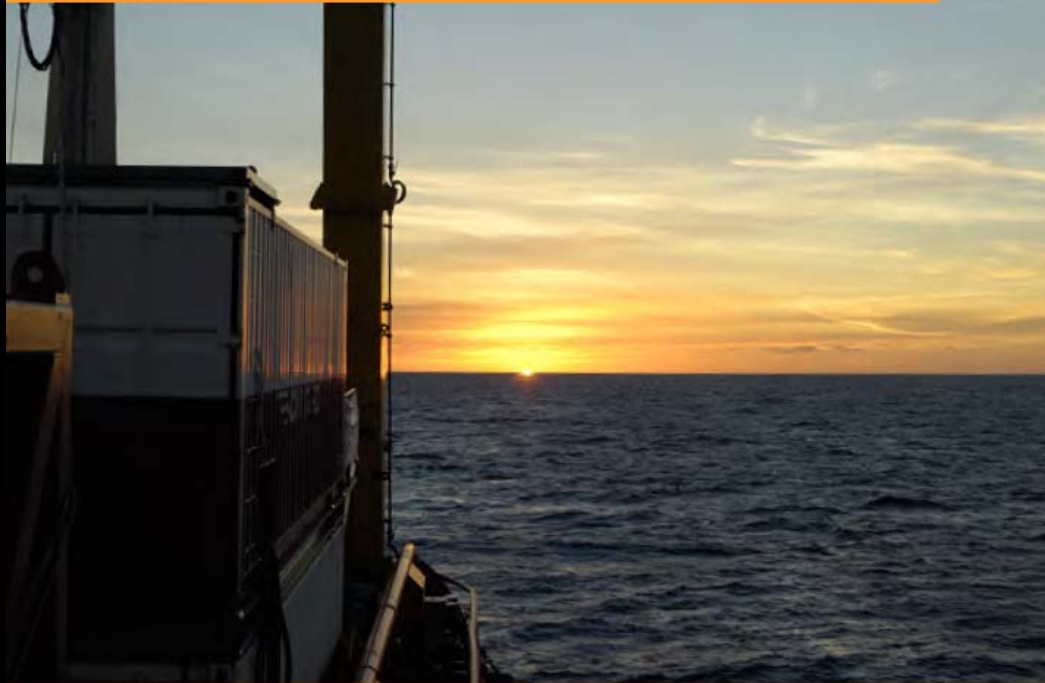
Science & education



Medicine



Environmental and Social Benchmarking Analysis of Nautilus Minerals Inc. Solwara 1 Project



EARTH
ECONOMICS

Report Outline

- Intro, history, demand/supply
- Copper Recycling & Substitution (Analysis I)
- State of Knowledge of the Bismarck Seabed
- Identification of Impacts (Analysis II)
- Quantification of Impacts (Analysis III)
- Monetization of Impacts (Analysis IV)
- Concentration & Smelting
- Conclusions & Recommendations

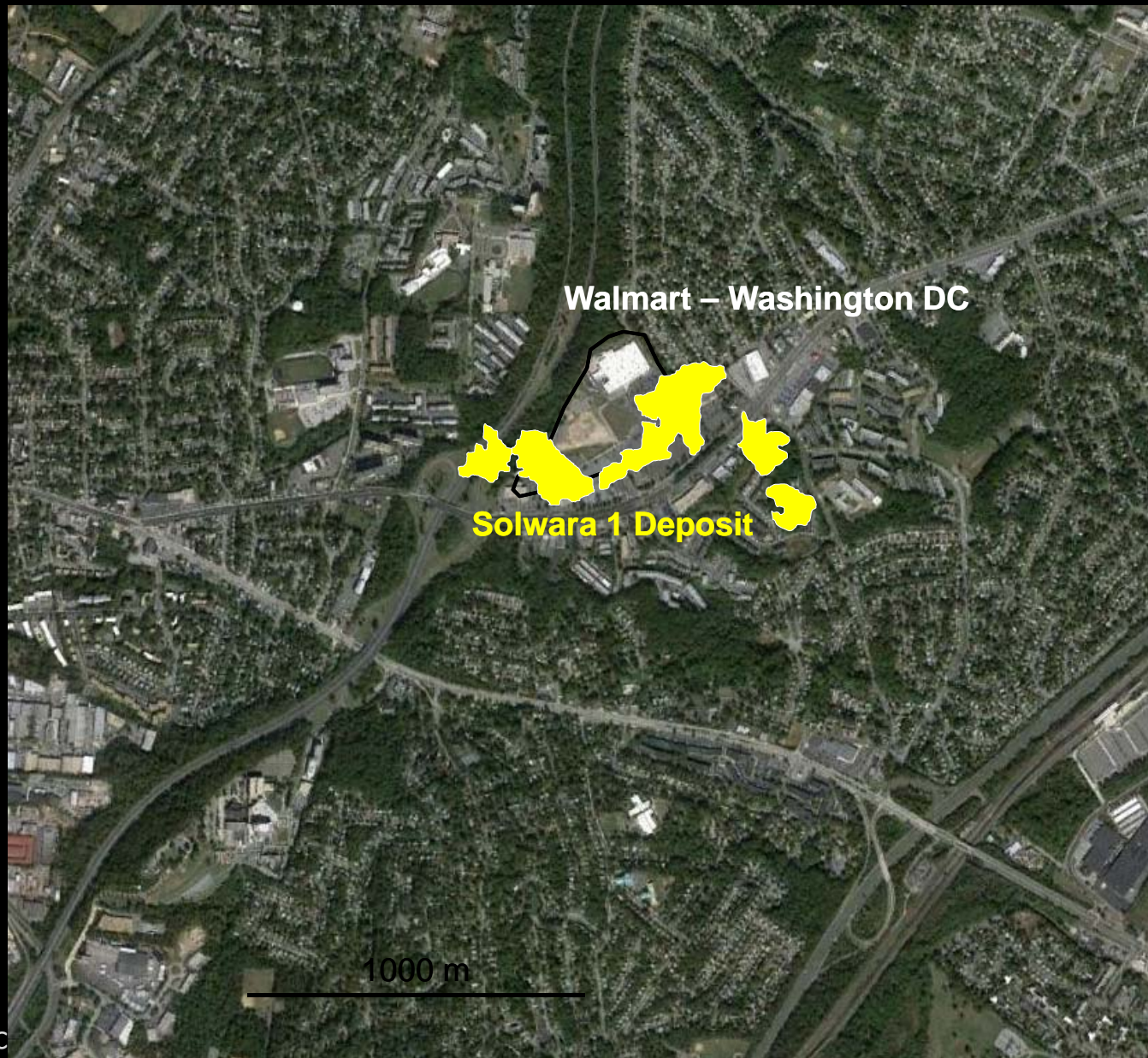


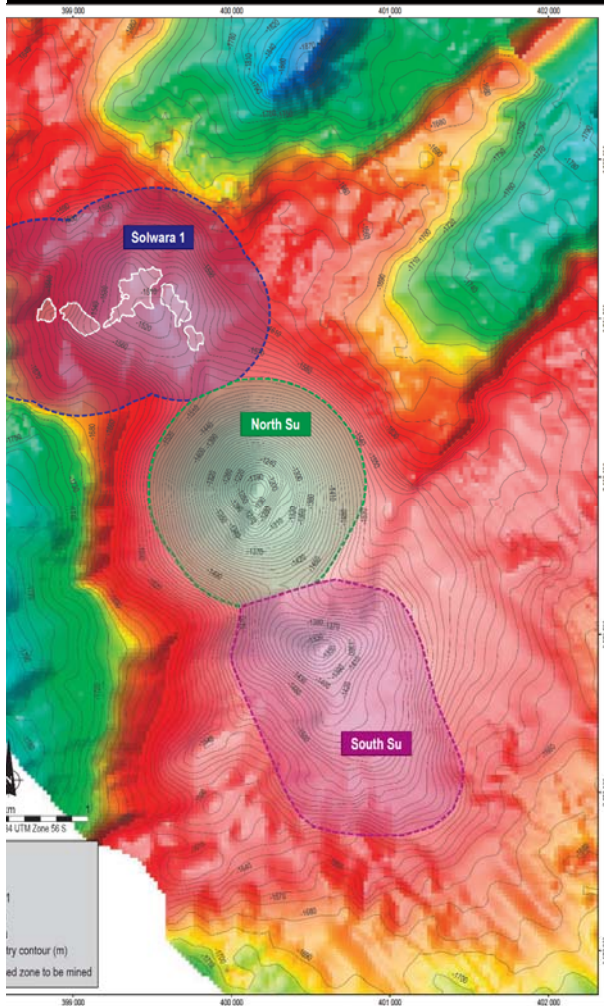
Identification of Impacts

Solwara 1 Project Location



Solwara 1 Project Scale - Shopping Centre





Site State of Knowledge is Strong

- 35+ independently published academic articles related to Solwara 1.
- May be the best studied 14 hectares of seabed on Earth.
- Vent systems in the Solwara 1 mine area exhibit dramatic disturbance, with vents naturally turning on and off with variations in volcanic activity.
- Studies indicate that the mine site could recover relatively quickly following disturbance, if adequate hard substrates and larval recruits are available.
- South Su reserve area will mitigate impacts on biodiversity.

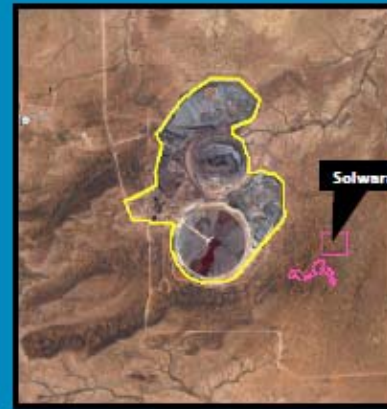
Solwara 1 Comparison Sites



▲ Bingham Canyon: Tailings Pond (above) and Mine (below)



▲ Solwara 1 Mine Site, with Tongling Refinery area* (square)



▲ Prominent Hill Mine



▲ Proposed Intag Mine*

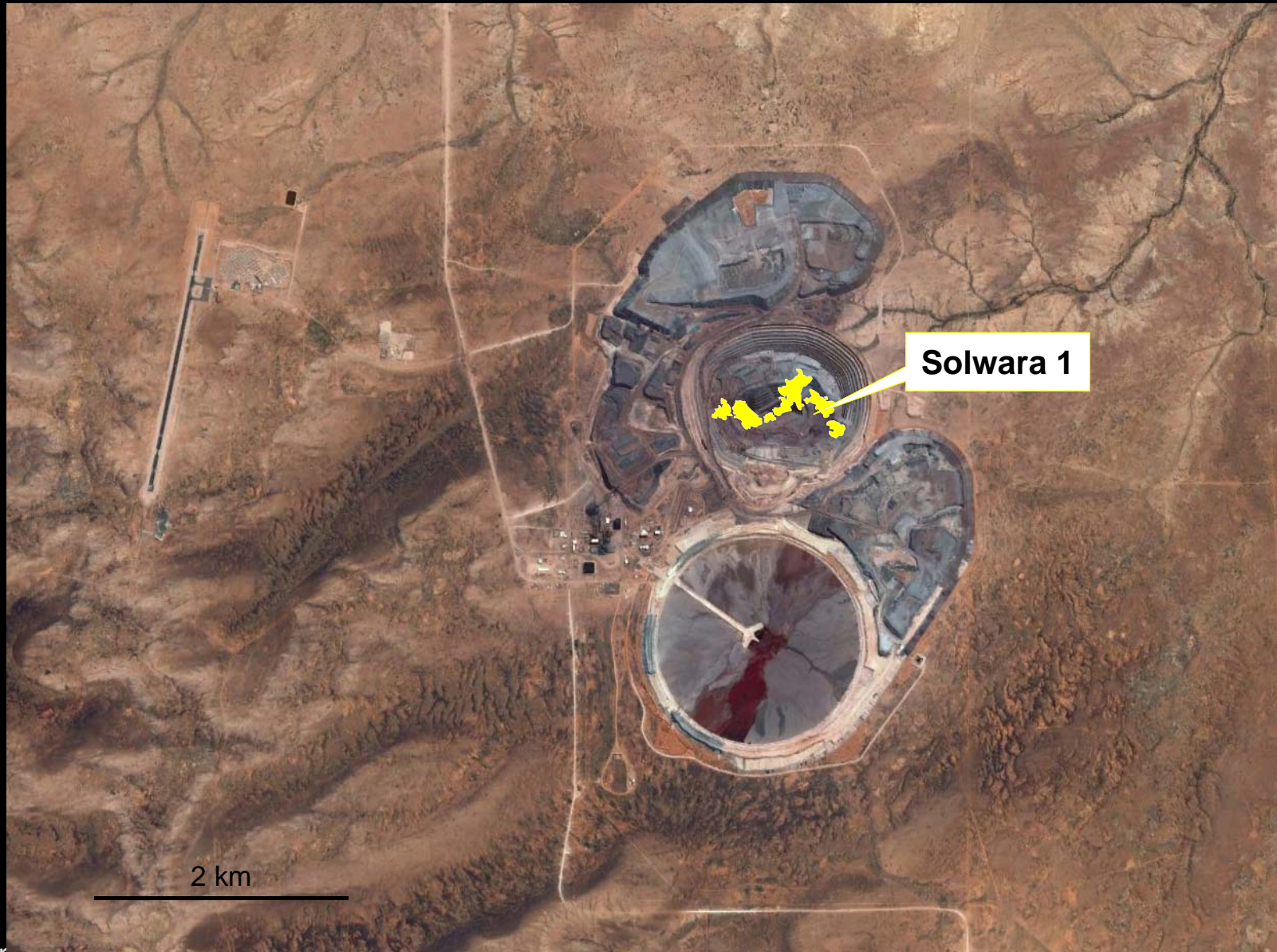


▲ JFK Airport, New York City
(for size comparison)

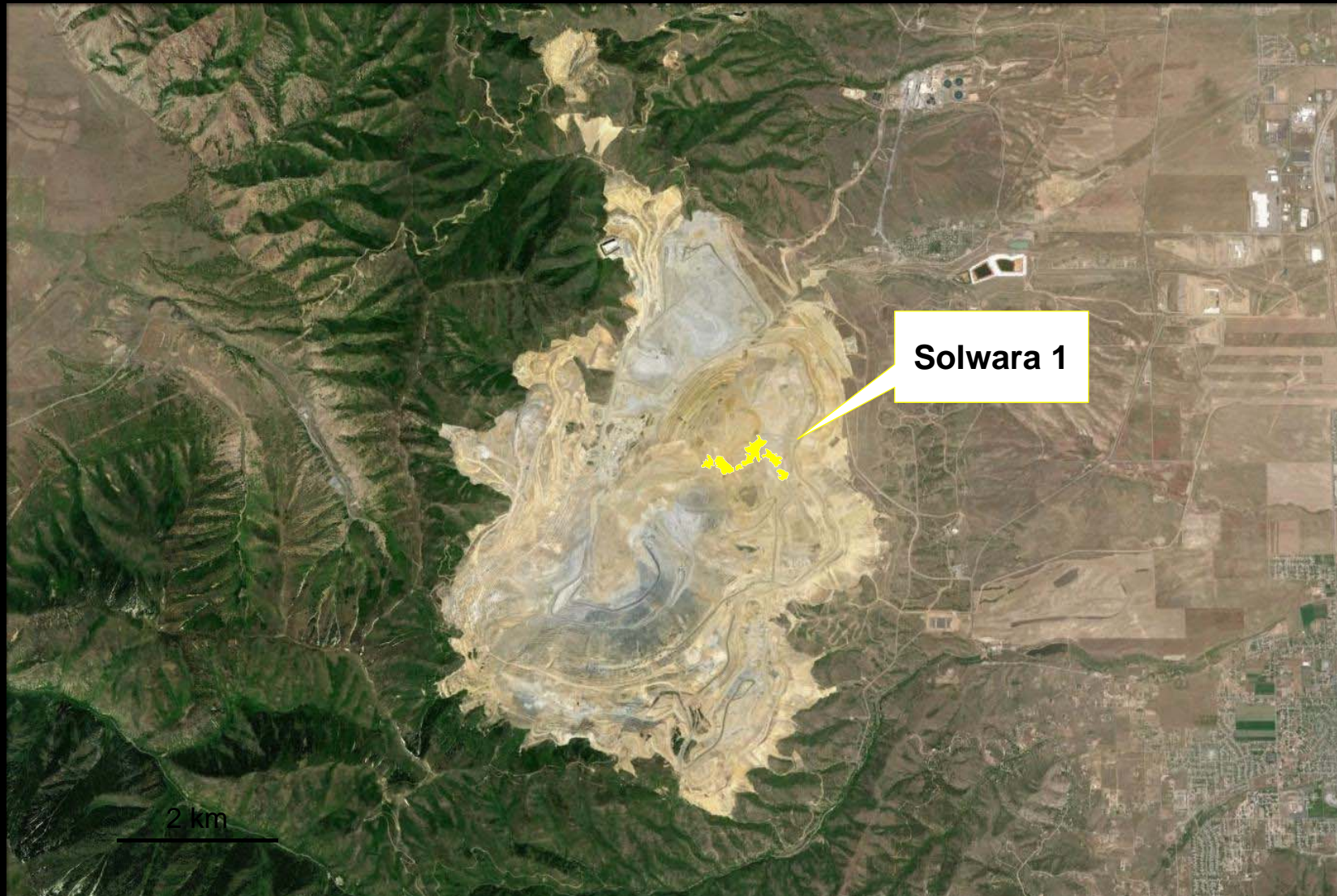


*This shape is not indicative of the overall footprint, as the design is not publically available

Prominent Hill, South Australia

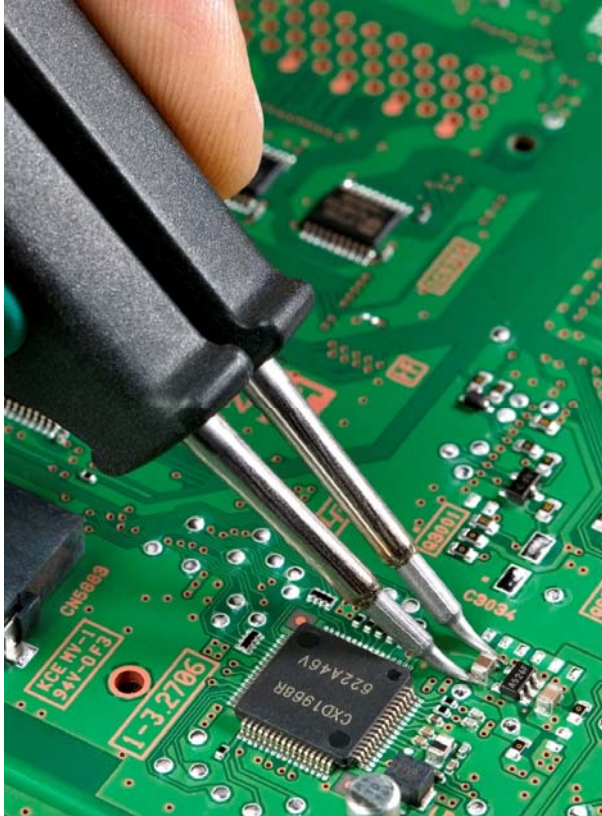


Bingham Canyon, Utah

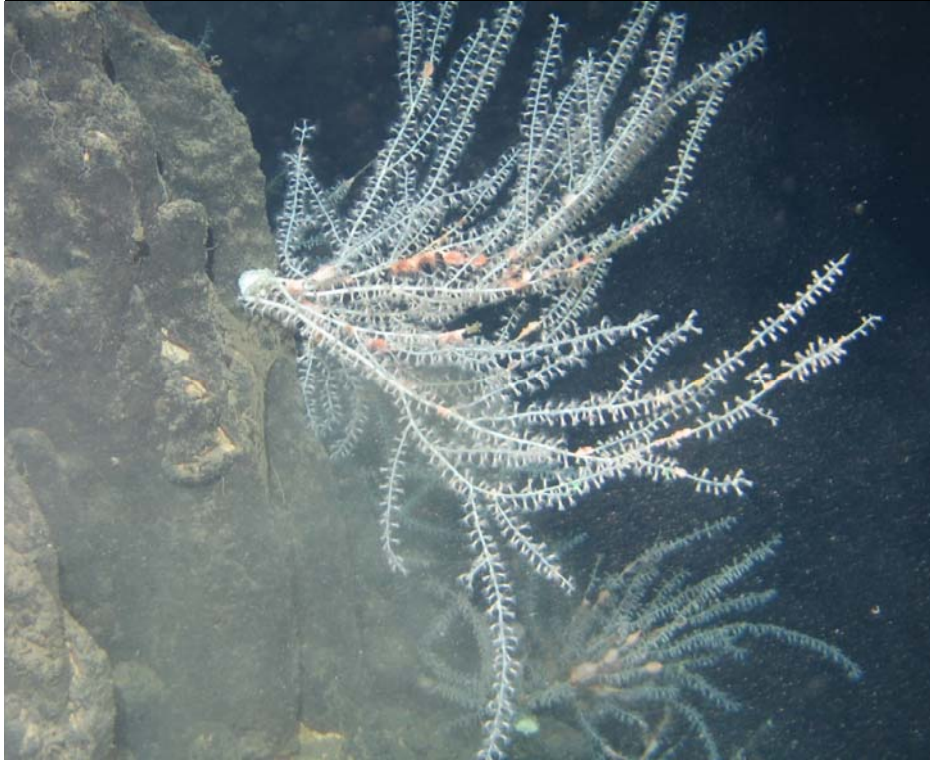


Ecosystem Service	Level of Impact (0 = lowest, 3 = highest)			
	Solwara 1	Prominent Hill	Bingham Canyon	Intag
Provisioning Services				
Food	0	1	3	3
Medicinal Resources	0	1	1	3
Ornamental Resources	0	0	0	1
Energy & Raw Materials	3	3	3	3
Water Supply	0	1	3	3
Regulating Services				
Biological Control	1	3	2	2
Climate Stability	1	1	2	3
Air Quality	1	0	1	1
Moderation of Extreme Events	0	1	3	3
Pollination	0	1	1	3
Soil Formation	0	3	3	3
Soil Retention	0	3	3	3
Waste Treatment	1	2	3	3
Water Regulation	0	1	3	3
Supporting Services				
Habitat & Nursery	2	2	3	3
Nutrient Cycling	1	2	3	2
Genetic Resources	1	3	3	3
Cultural Services				
Natural Beauty	1	1	3	2
Cultural and Artistic Information	0	1	2	3
Recreation and Tourism	0	0	3	3
Science and Education	1	3	1	2
Spiritual and Historic	0	3	1	3

Conclusions



- Solwara 1 mine involves fewer potential impacts than comparison sites, ranked across the 22 categories of natural capital accounting.
- People will not be displaced by the Solwara 1 deep seabed copper mine.
- **Not Impacted by Solwara 1:**
 - Food production, fresh water supply, disaster risk reduction, pollination, soil formation, erosion, freshwater regulation, recreation, historic & cultural values.
- **Impacted by Solwara 1:**
 - Raw materials, biological control, climate stability, air quality, waste treatment, habitat and nursery, nutrient cycling, biodiversity, genetic resource values, science and education.



Quantification of Impacts

Quantified Impacts: Solwara 1 vs. Comparison Mines

	Measure	Annual Cu Production	Total Cu Production	Freshwater Use	Energy Use	CO ₂ Emissions	Mineral Waste	Area of Disturbance
	Unit	Metric tons	Metric tons	Liters per metric ton of Cu produced	MWh per metric ton of Cu produced	Metric tons of CO ₂ per metric ton of Cu produced	Metric tons of tailings & waste rock per metric ton of Cu produced	Square meters per metric ton of Cu produced
COMPARISON MINES	IMPACT TYPE							
Solwara 1 (proposed) Total ^{46,48}	Mine + Refinery	77,760 ⁸⁶	127,186 ⁸⁷	0	4.0	3.6	1.9	5.4
<i>Solwara 1 Mine</i>	<i>Mine</i>			0	4.0	3.6	1.9	1.1
<i>Tongling Refinery</i>	<i>Refinery</i>			Data not available	Data not available	Data not available	0	4.3
Prominent Hill Total	Mine + Refinery	73,362 ⁸⁹	2,046,000 ⁸⁹	83,831 ⁹⁰	15.3 ⁹¹	5.4 ⁹²	36.3 ⁹³	7.2 ⁹⁴
Bingham Canyon Total	Mine + Refinery + Smelter	194,000 ⁹⁵	19,000,000 ⁹⁶	21,041 ⁹⁷	24.8 ⁹⁸	7.7 ⁹⁹	11.5 ¹⁰⁰	5.4 ¹⁰¹
Intag (proposed) Total	Mine	484,437 ¹⁰²	9,906,472 ¹⁰³	Data not available	Data not available	Data not available	11.5 ¹⁰⁴	5.4 ¹⁰⁵

Downslope impacts and liabilities are not present

Social impacts not present

Fresh water impacts not present





Monetization of Impacts

Bingham Canyon Ecosystem Service Impacts

	Developed, Open Space/M-low Density	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub	Grasslands	Pasture/Hay	Cultivated	Woody Wetlands	Emergent Herbaceous Wetland
Ecosystem Service	Value (\$/hectare/year)									
Food			\$78	\$39		\$90		\$22,560		\$877
Medicinal Resources										
Ornamental Resources										
Energy and Raw Materials		\$48	\$10	\$29				\$356		
Water Supply										
Biological Control										
Climate Stability										
Air Quality	\$579	\$670	\$410	\$540				\$251		
Moderation of Extreme Events	\$319		\$1,682	\$841					\$18,270	\$7,694
Pollination										
Soil Formation										
Soil Retention			\$2	\$1		\$18	\$15	\$325		
Waste Treatment			\$516	\$258					\$14,064	\$38,684
Water Regulation	\$1,083					\$4		\$121	\$2,644	\$6,503
Habitat & Nursery			\$9,496	\$4,748	\$828	\$87	\$12	\$736	\$35,791	\$14,688
Nutrient Cycling										
Genetic Resources										
Natural Beauty	\$57,805	\$1,217		\$609			\$13	\$217	\$17,683	\$15,559
Cultural and Artistic Information										
Recreation and Tourism		\$742	\$15,922	\$8,332	\$481	\$285		\$68	\$18,646	\$13,121
Science and Education										
Spiritual and Historic										
Total	\$59,785	\$2,678	\$28,116	\$15,397	\$1,309	\$484	\$40	\$24,634	\$107,097	\$97,126

Land Cover Type	Area (hectares)	Value (\$/hectare/year)	Value of Impacts to Ecosystem Services (\$/year)
Open Water	4	\$0	\$0
Developed, Open Space	129	\$59,785	\$7,697,270
Developed, Low Intensity	205	\$59,785	\$12,262,929
Developed, Medium Intensity	183	\$0	\$0
Developed, High Intensity	49	\$0	\$0
Barren	179	\$0	\$0
Deciduous Forest	242	\$2,678	\$648,584
Evergreen Forest	524	\$28,116	\$14,724,095
Mixed Forest	1	\$15,397	\$12,282
Shrub/Scrub	838	\$1,309	\$1,096,636
Grassland/Herbaceous	242	\$484	\$117,206
Pasture/Hay	302	\$40	\$12,153
Cultivated Crops	96	\$24,634	\$2,364,458
Woody Wetlands	27	\$107,097	\$2,862,971
Emergent Herbaceous Wetlands	11	\$97,126	\$1,066,274
Total	3,031		\$42,864,859

Summary of Ecosystem Service Impacts

Mine	Annual Value of Ecosystem Service Impacts	Net Present Value of Ecosystem Service Impacts	Total Copper Production for Lifetime of Mine (metric tons)	Relative Impact on Ecosystem Services per Ton of Copper Produced
Solwara 1 (proposed)	\$24,724	\$605,871	127,186	1.0
Prominent Hill	\$1,919,065	\$47,026,675	2,000,000	4.9
Bingham Canyon	\$42,864,859	\$1,050,403,319	17,000,000	13.0
Intag (proposed)	\$8,797,585	\$215,584,802	9,906,472	4.6

Framework for Evaluating Mining

Who's Interested?
Investors, Lenders, Insurers,
Reinsurers, Guarantors



Thank You

dbatker@eartheconomics.org

