

First outcomes of the review and rapid assessment on implementation of the transboundary demonstration project at the Tuyamuyun Hydroelectric Complex (THC)

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Deltares

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Content (1/2)

Synopsis

Part 1: Study of information on the operation of the THC and its current state

Introduction – Nexus and reservoir sustainability

- Reservoirs and Water-Food-Energy-Environment (WFEE) Nexus
- Reservoir management considering Ecosystem Services (ES) and Sustainable Development Goals (SDGs)
- Integrated and Participatory Management (IPM)
- Applicability to Tuyamuyun Hydro-Complex (THC)

Revisiting the sediment-induced problems the THC

- Understanding of the system (catchment to reach scales)
- Reviewing available data and information, their usability and gaps
- Assessing magnitude and specifics of the sediment-induced problems at THC

Content (2/2)

Part 2: Screening of the possible technical measures based on the review and global practices

Management of sediment induced problems considering beneficial reuse

- General practices on managing sediment-induced problems in reservoirs
- Practices on beneficial reuse of sediment

Management of sediment-induced problems at THC:

- Characterization of sediment-induced problems at THC
- First screening of possible measures
- Challenges and limitations

Discussion and way forward

Synopsis

Synopsis (1/3)

- ❑ Sediment-induced problem at Channel reservoir of THC is significant and serious (there is no specific data and information about the problems at other off-channel reservoirs).
- ❑ There are two major impacts, viz. (i) a large deposition near the spillway and hydropower intakes leading to poor functioning of the hydropower and clogging of undersluices, and (ii) large deposition along the reservoir (mainly along 50 km upstream of the dam) leading to significant storage loss (of about 63%).
- ❑ Handling the problem near the dam area requires local sediment removal using appropriate dredging technology including some manual work.
- ❑ Handling the problem of storage loss and improving water availability most likely requires combination of multiple measures given the large amount of deposited materials. For the comparison: About 200 million m³ of sediment is dredged annually in whole Europe (25 mln. m³ in The Netherlands).

Synopsis (2/3)

- ❑ First screening of reuse options at THC reveals following possibilities to be explored and discussed: (i) Manufactured topsoil enhancement and fertilizers for agricultural use; (ii) land reclamation and land filling; (iii) construction materials/ engineered structural fill; (iv) river management, habitat creation and restoration.
- ❑ Since the volume is very large, the only removal option may not be feasible technically, economically and environmentally. Therefore, feasibility of another option (in combination with sediment removal with beneficial reuse), viz. enhancement of existing as well as creation of new off-channel reservoirs, should be considered as well (to increase water availability).
- ❑ One of the critical problems is disposal of dredged materials, so the sediment removal may only be viable if the reuse options are sustainable. It appears that there is availability of good space to create the disposal and treatment facilities (this is not always the case in other countries).

Synopsis (3/3)

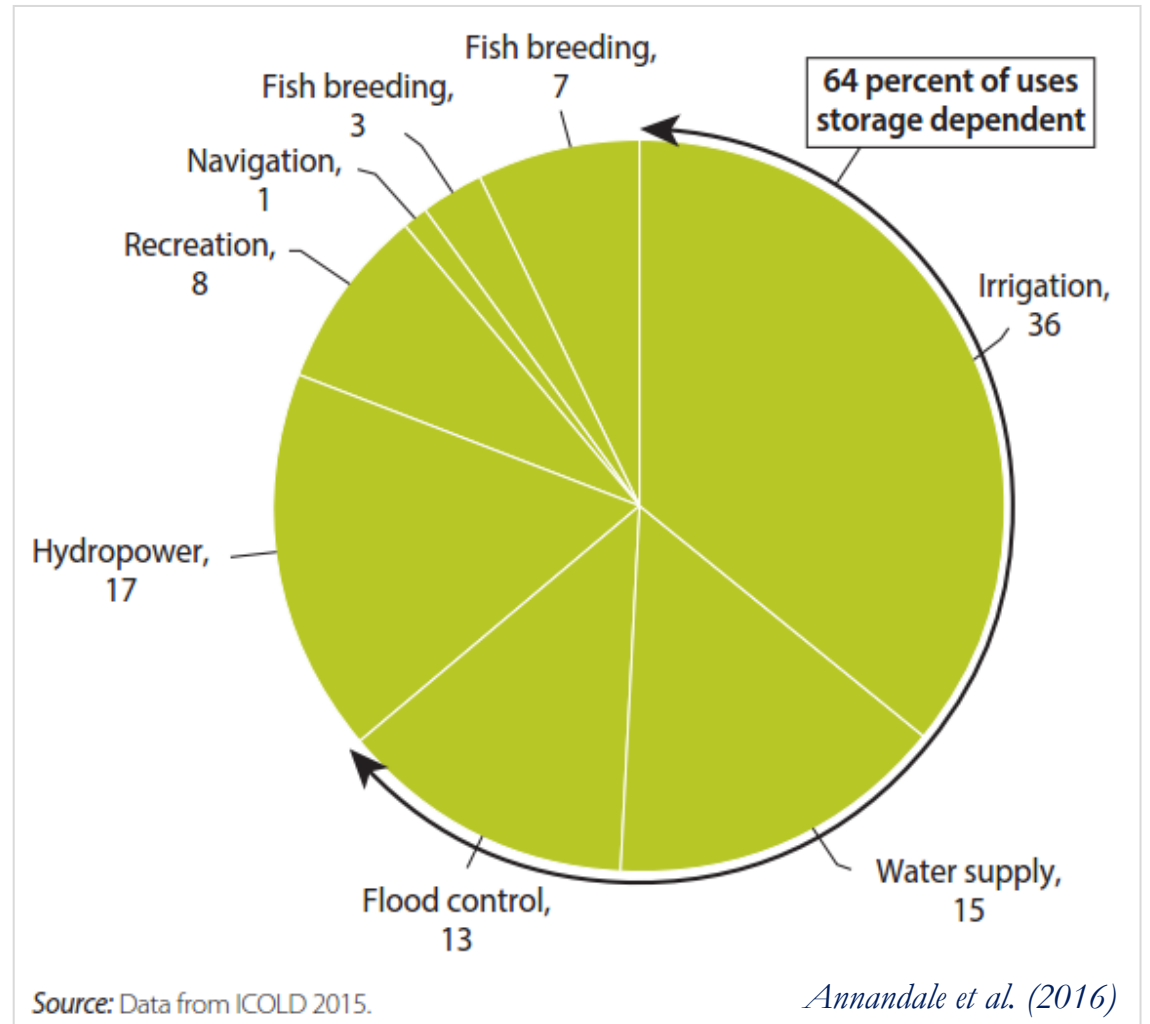
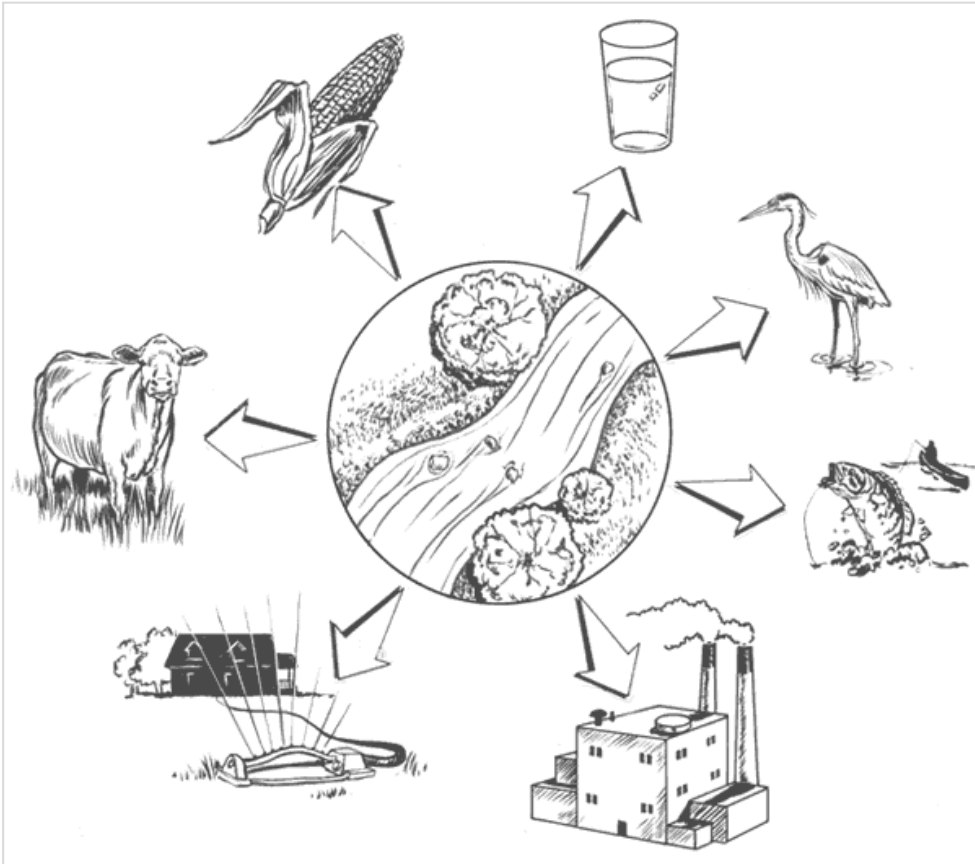
- ❑ It is important to quantify and analyse the physical, biological and chemical characteristics of deposited materials to assess their suitability and to select the processing and treatment methods and techniques. The analysis will dictate the (i) contaminant adsorption; and (ii) realistic beneficial use outcomes.
- ❑ An integrated approach is required considering optimal use of water, efficient agricultural methods and practices, minimizing water loss/use and pollution as well as catchment/river/land-use management in complement with establishment of proper water and sediment monitoring, information, forecasting and reservoir operation systems including regular R&D activities.
- ❑ Since the THC is a transboundary complex with multiple users, the involvement of all stakeholders as well as close cooperation between two countries are very important criteria for the selection and execution of optimal measures for its rehabilitation and management.

Part 1

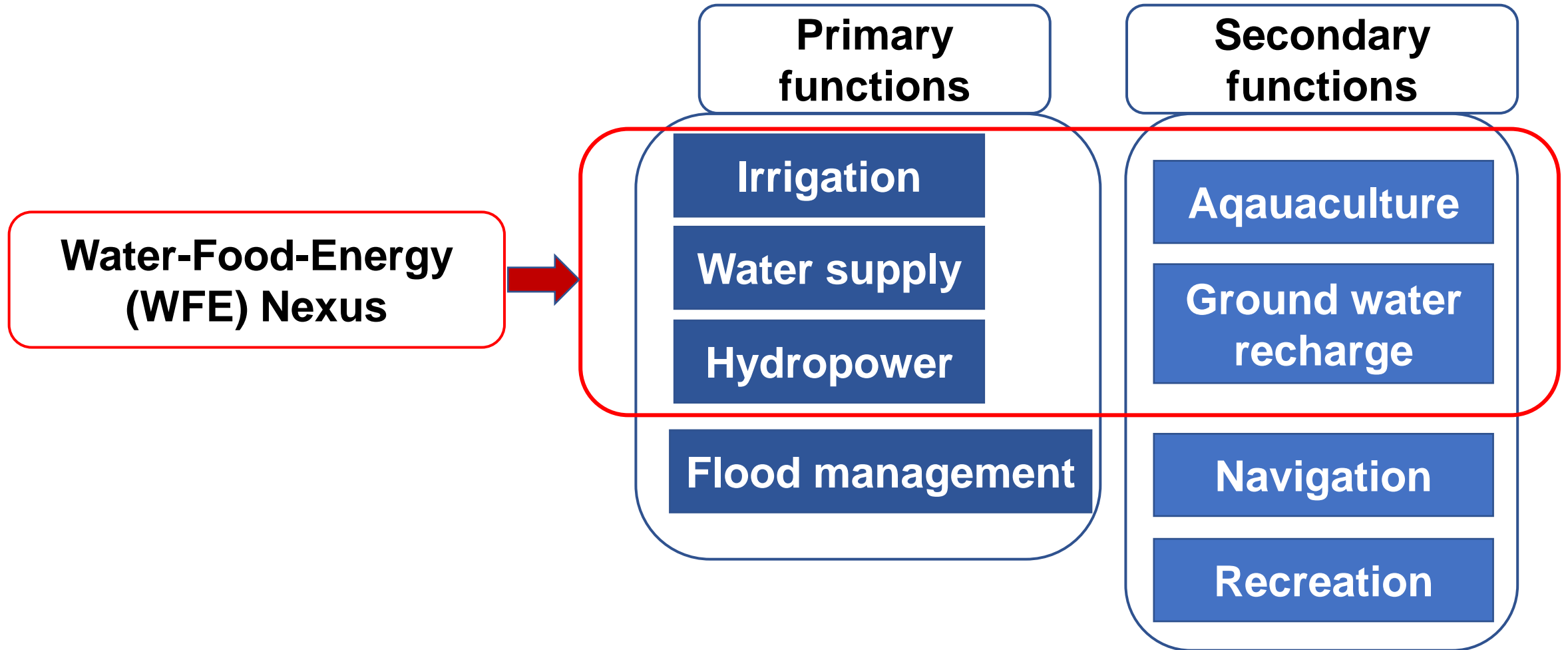
**Study of information on the operation of the
THC and its current state**

Introduction - Nexus and reservoir sustainability

Reservoirs - An integral part of water resources and flood management

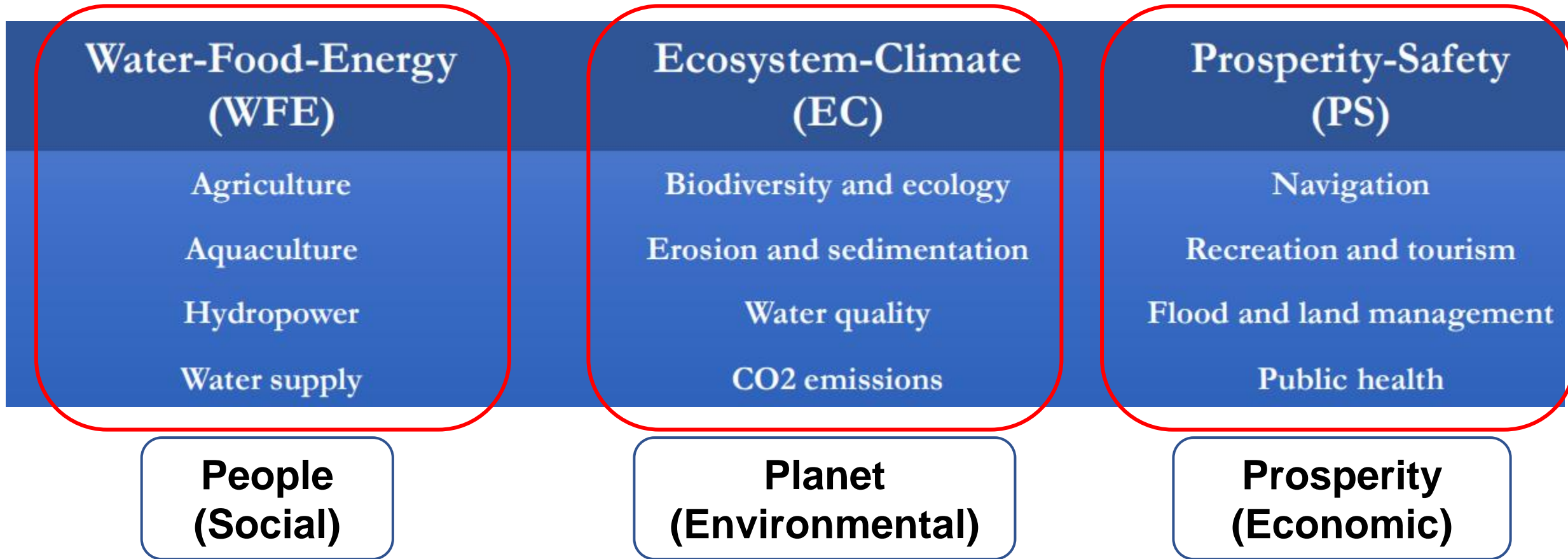


Nexus and reservoir sustainability (1/3)



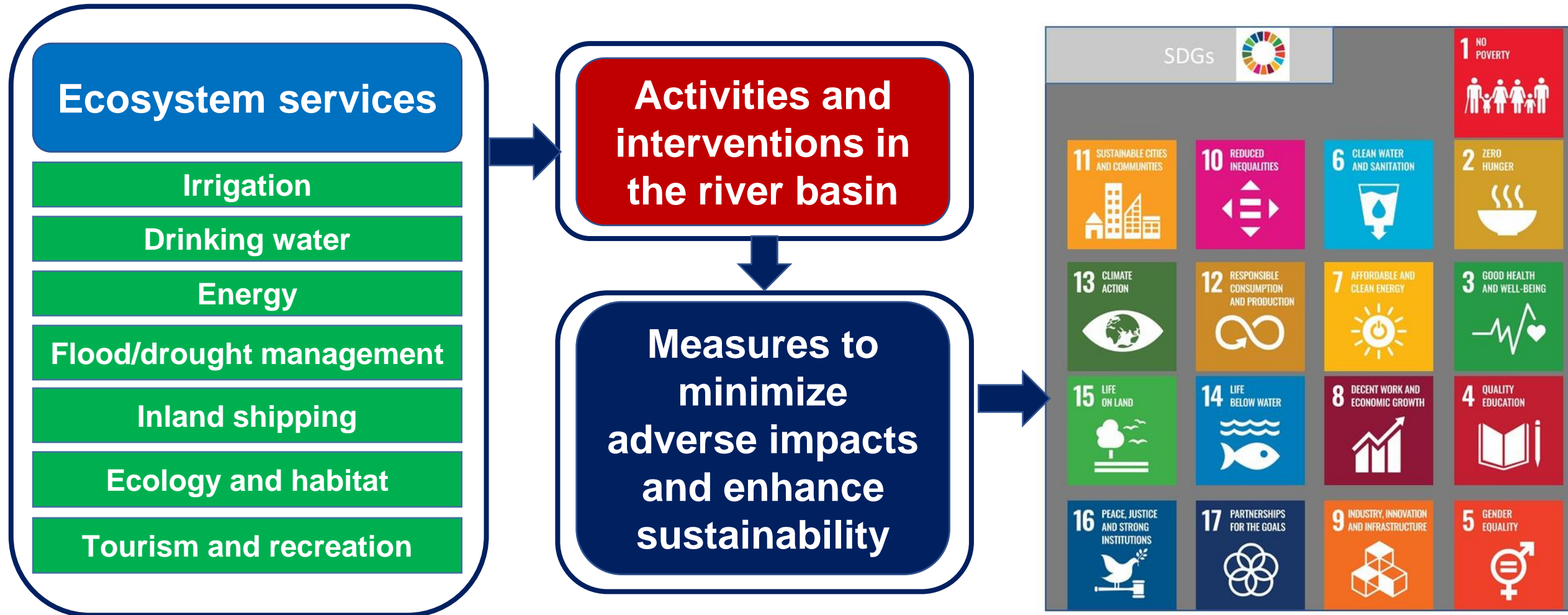
Nexus and reservoir sustainability (2/3)

WFE + Environment (WFEE) as an integral part of reservoir sustainability



Nexus and reservoir sustainability (3/3)

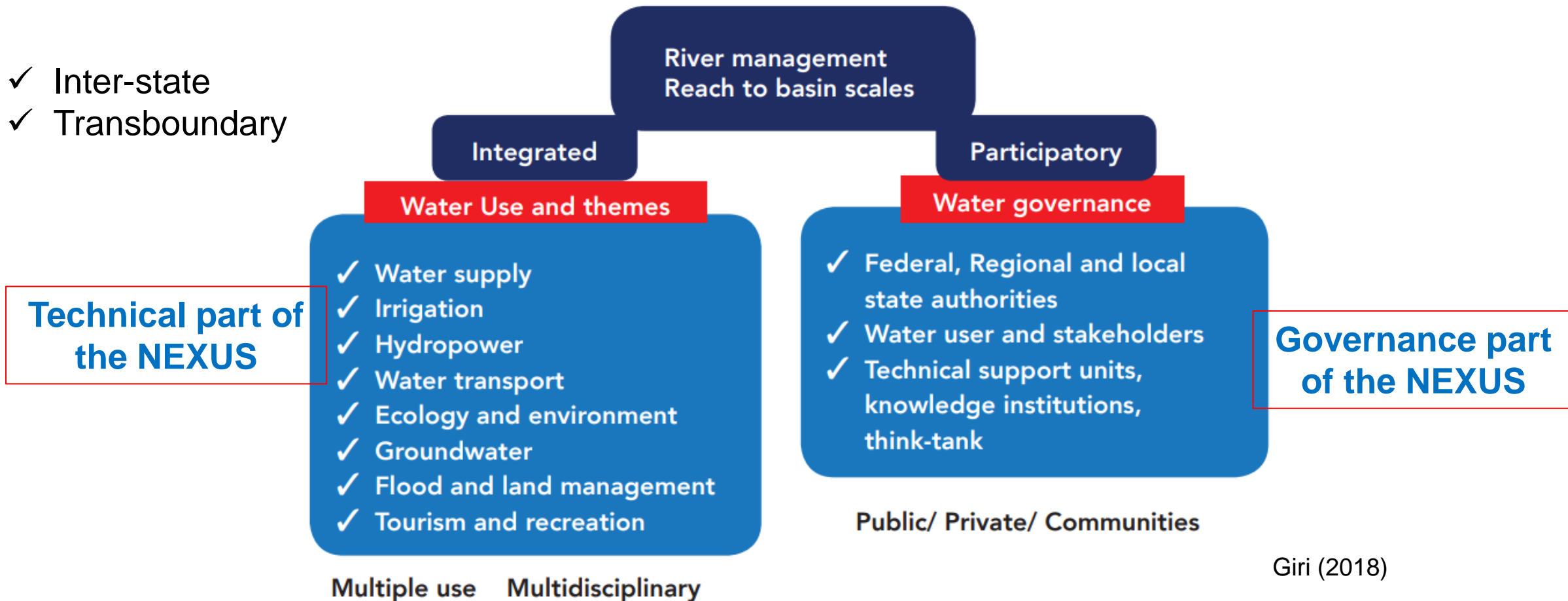
Connection to Ecosystem Services (EC) and Sustainable Development Goals (SDGs)



Integrated and Participatory Management (IPM) (1/2)

Sustainable reservoir management - A part of integrated river basin management

- ✓ Inter-state
- ✓ Transboundary

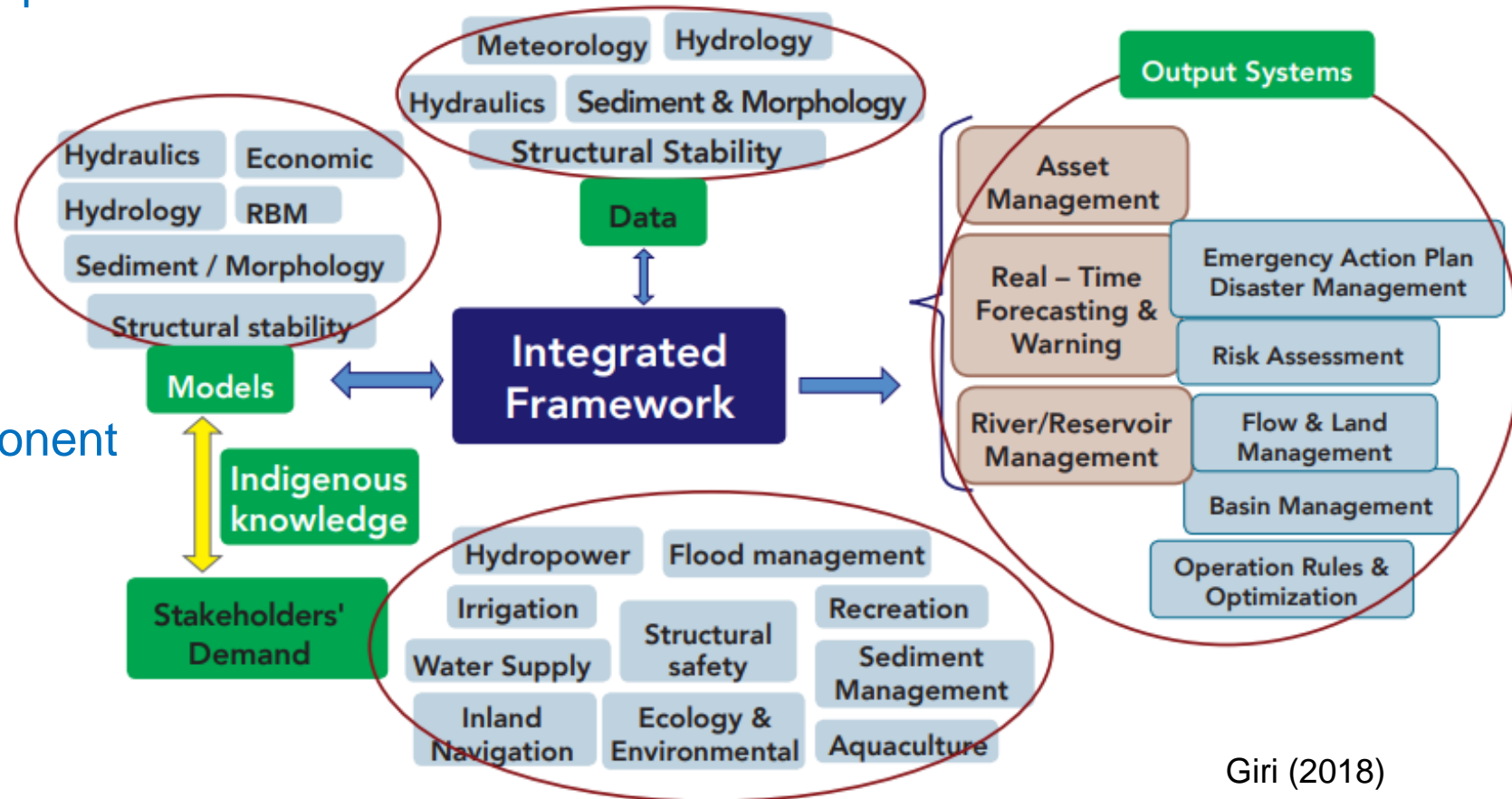


Integrated and Participatory Management (IPM) (2/2)

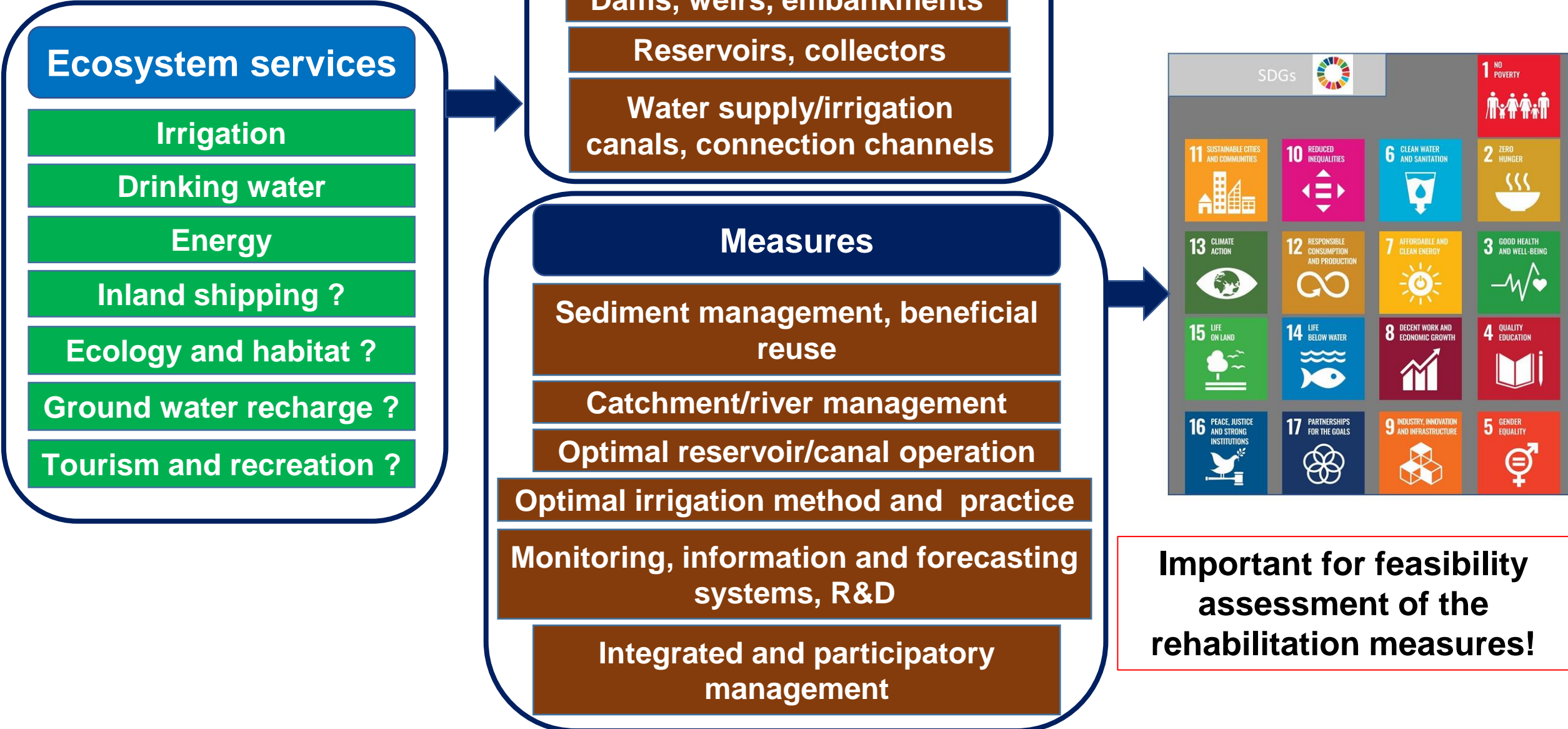
An example framework of integrated multidisciplinary knowledge base platform for supporting integrated management

Non-structural component

Non-structural component



Applicability to THC



Revisiting the sediment-induced problems at the THC

Understanding of the system (1/12)

Amu Darya River

- The largest river in Central Asia, with a catchment area of **534,739** km² and length of **2,620** km.
- A transboundary river shared by Afghanistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan
- Flow contribution from Tajikistan (=72.8%), Afghanistan (=14.6%) and Uzbekistan (=8.5%). Three major tributaries: Kafirnigan, Sherabad, and Surkhan Darya (also Vakhsh, Zeravshan). About 61% of the drainage lies within Tajikistan, Uzbekistan and Turkmenistan, while 39% is in Afghanistan.
- The annual flow volume of the Amu Darya is **73.6** km³ with a storage capacity of 24 billion m³
- Almost 80% of the Amu Darya is regulated by over 35 reservoirs with a capacity of over 10 **million (billion?)** m³ - two main reservoirs, Nurek and Tuyamuyun, and several other reservoirs on the Karakum, Karshi and Amu-Bukhara canals along the main river and tributaries.



Verify these information!

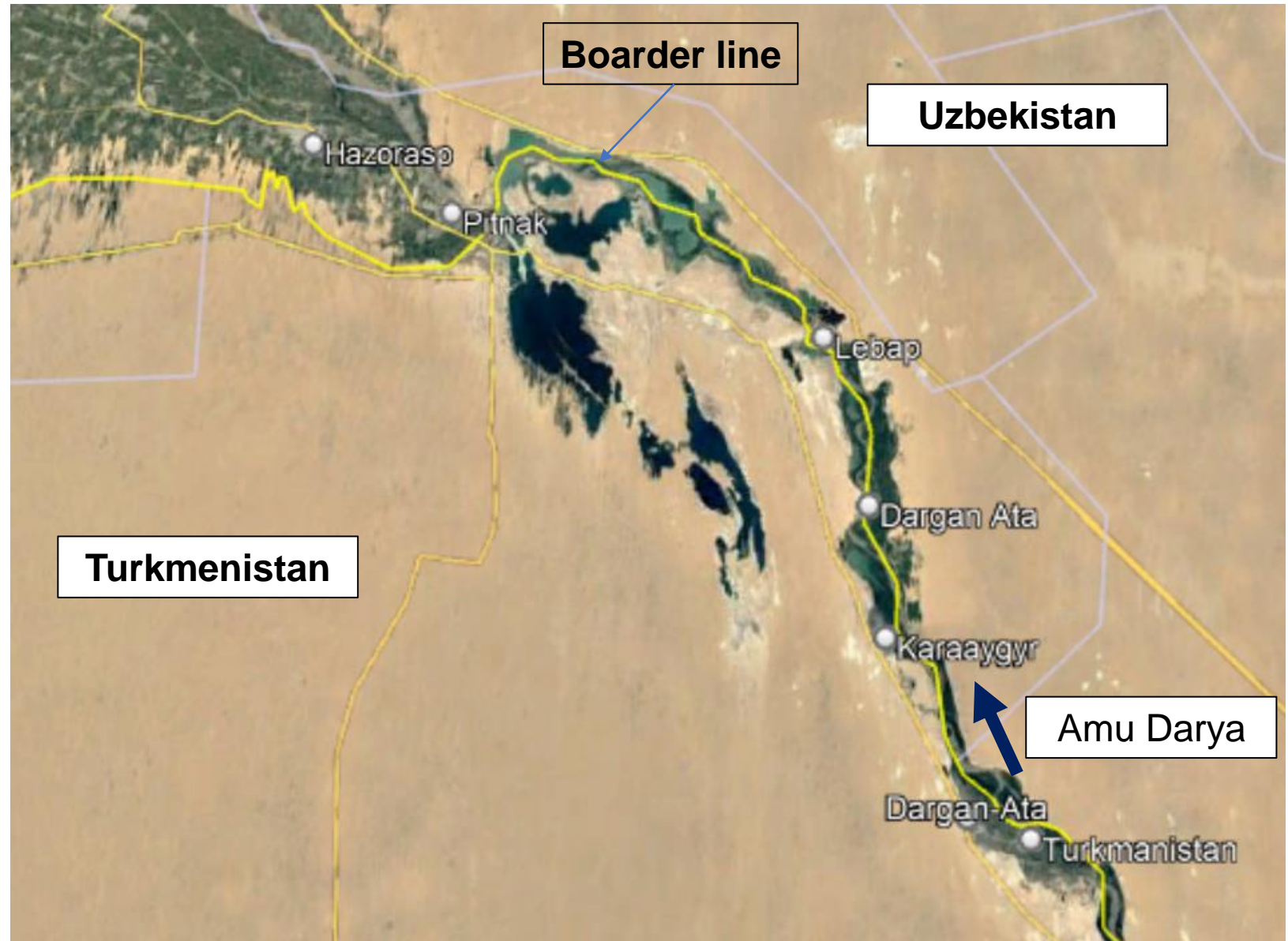
[Amu Darya - Wikipedia](#)

[Amu Darya River Basin | Amu Darya Basin Network](#)

Understanding of the system (2/12)

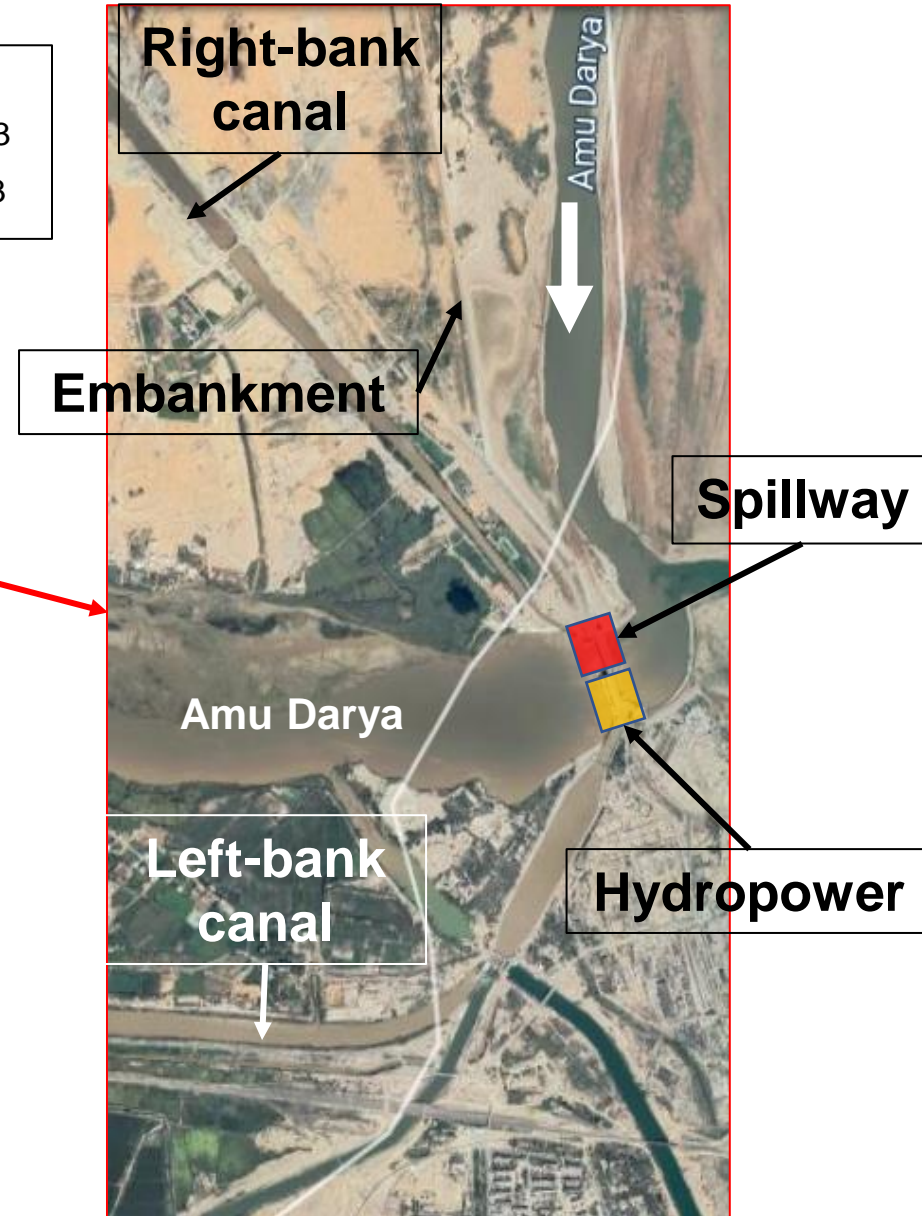
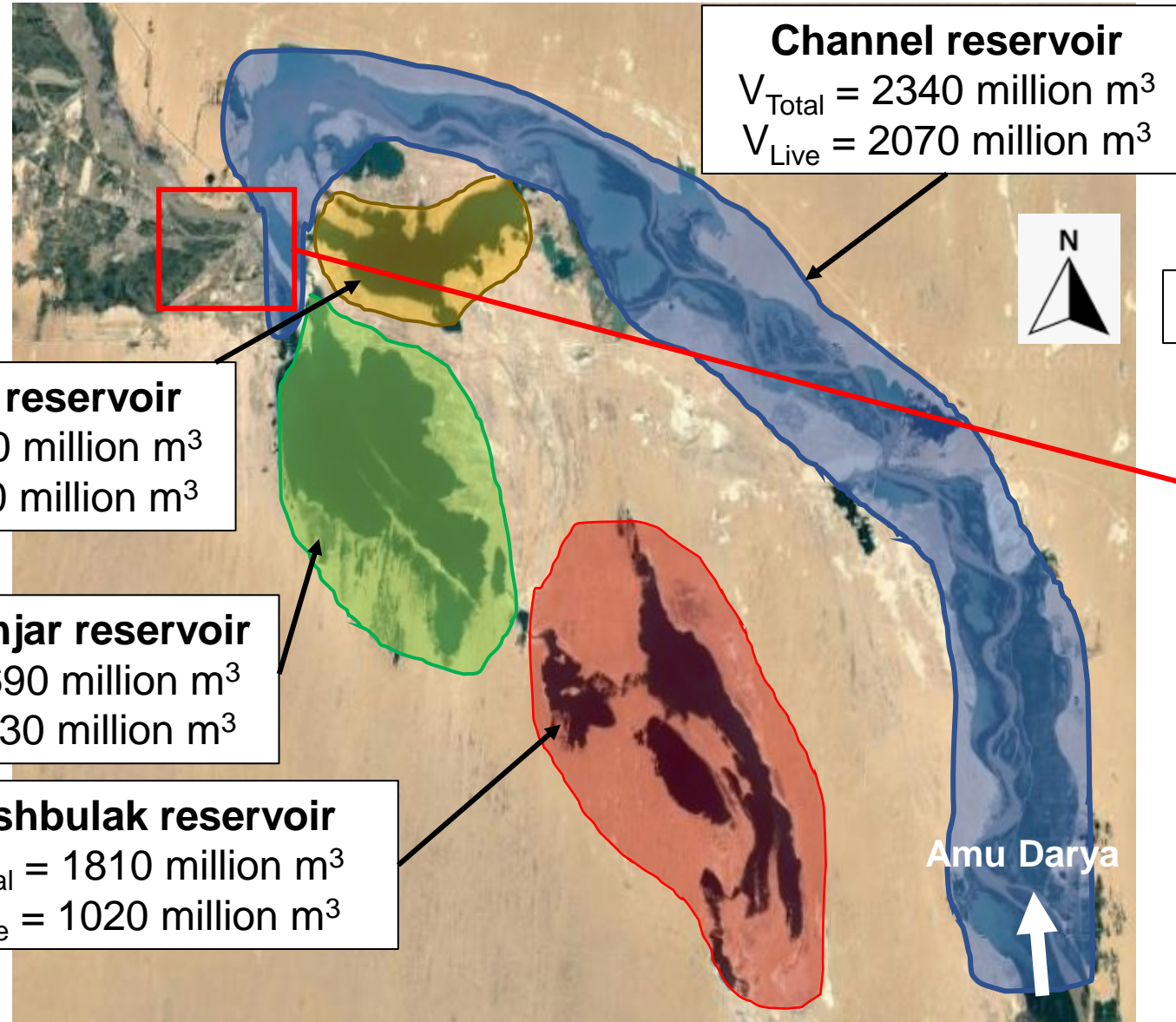
A multipurpose complex

- ✓ Irrigation
- ✓ Water supply
- ✓ Hydropower



Understanding of the system (3/12)

Tuyamuyun Hydro-Complex (THC)



Understanding of the system (4/12)

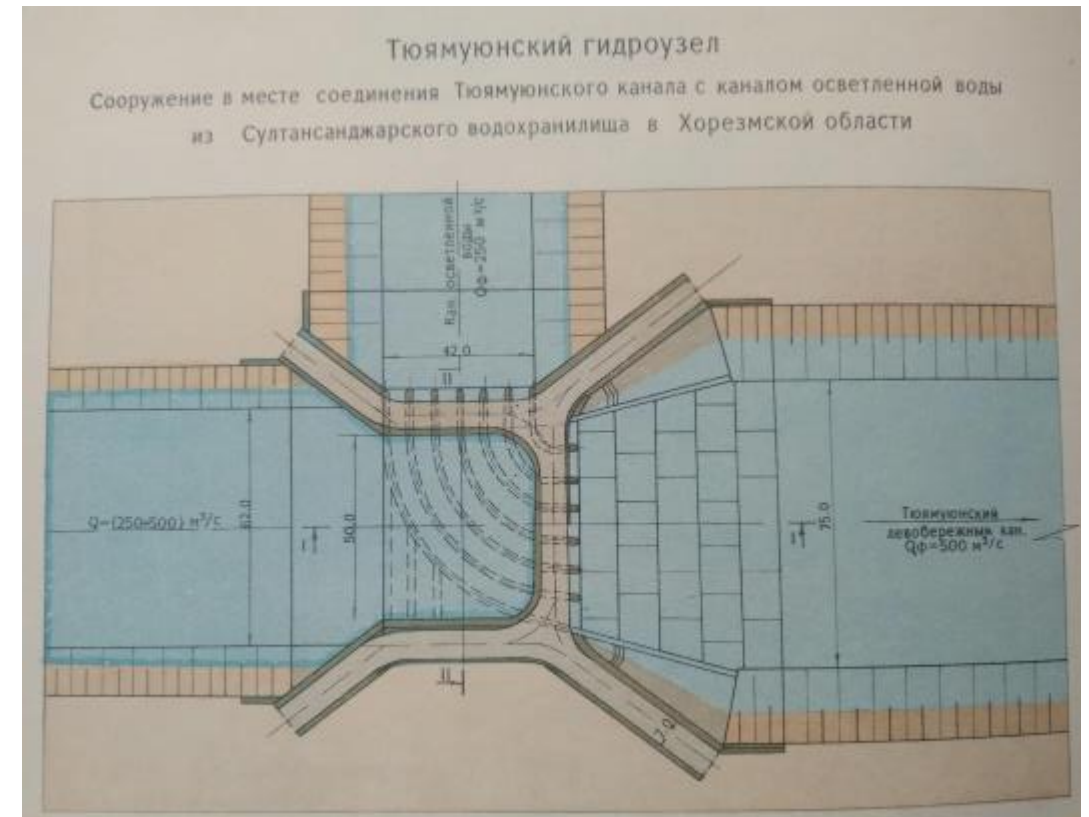
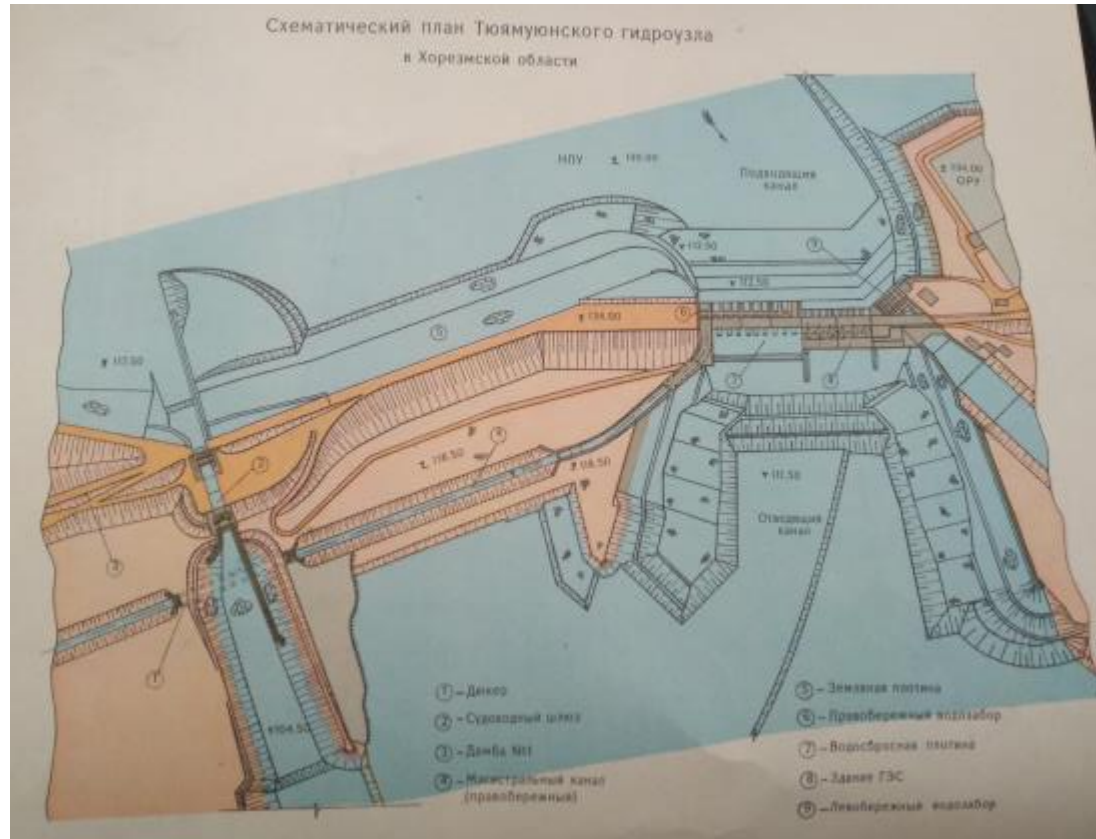
Salient feature of headworks

- Commissioned year – 1980
- Full Reservoir Level (FRL) = 130 m
- Minimum Drawdown Level (MDDL) = 120 m
- Original bottom level near the dam = 110 -112.5 m
- Spillway length/ height = 141 m/ 34 m (Head = 24 m)
- Spillway (with 8 gates) capacity = 920 m³/s (each gate?)
- Undersluice capacity = 8700 m³/s
- Spillway crest level = 120 m
- Sill level of undersluice = 110 m
- Earthen dam height/ length = 34 m /900 m
- Earth dam crest level = 134 m
- Hydropower = 25 MW*6 turbines = 150 MW



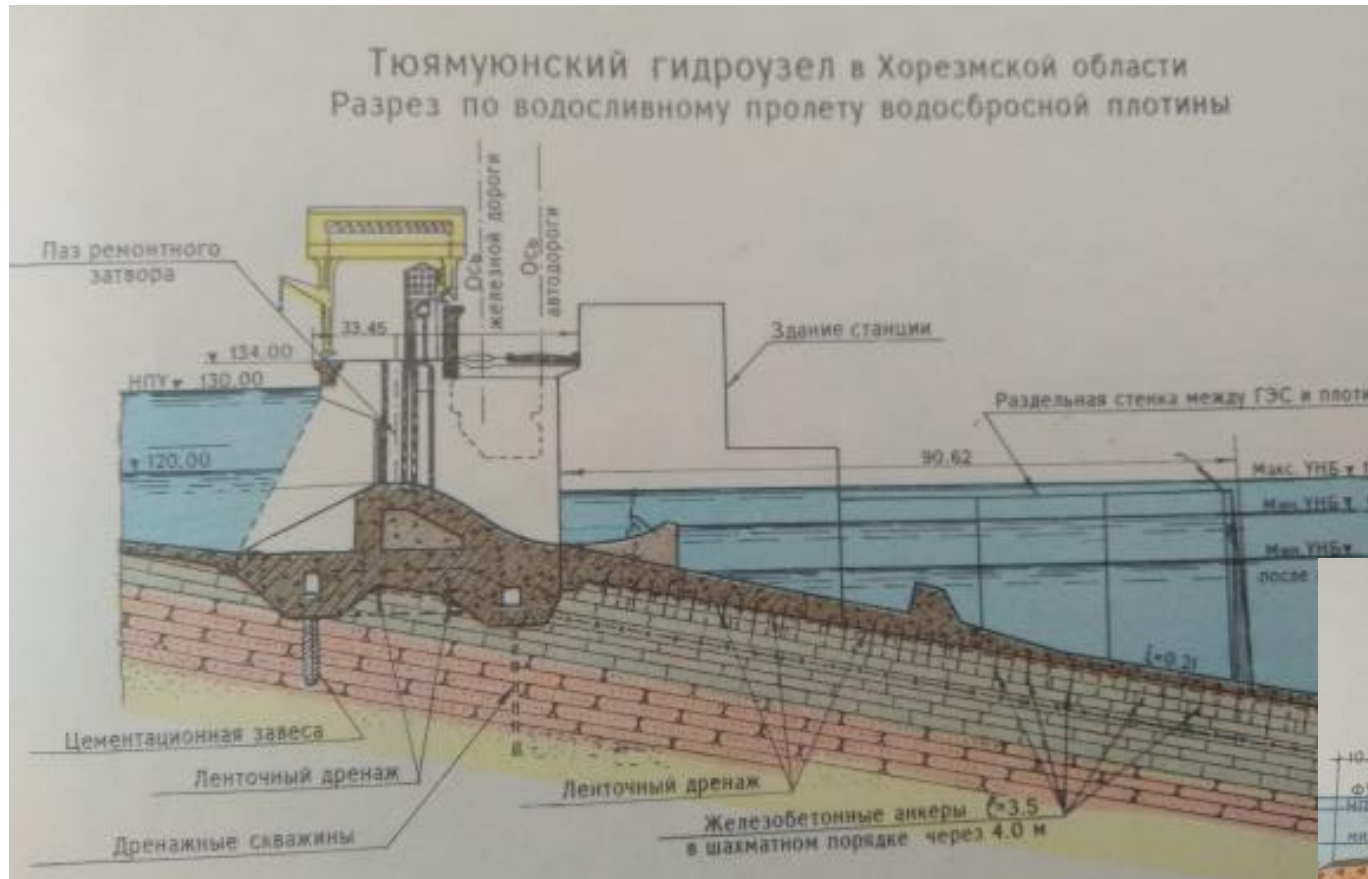
Understanding of the system (5/12)

Headworks and reservoir connection



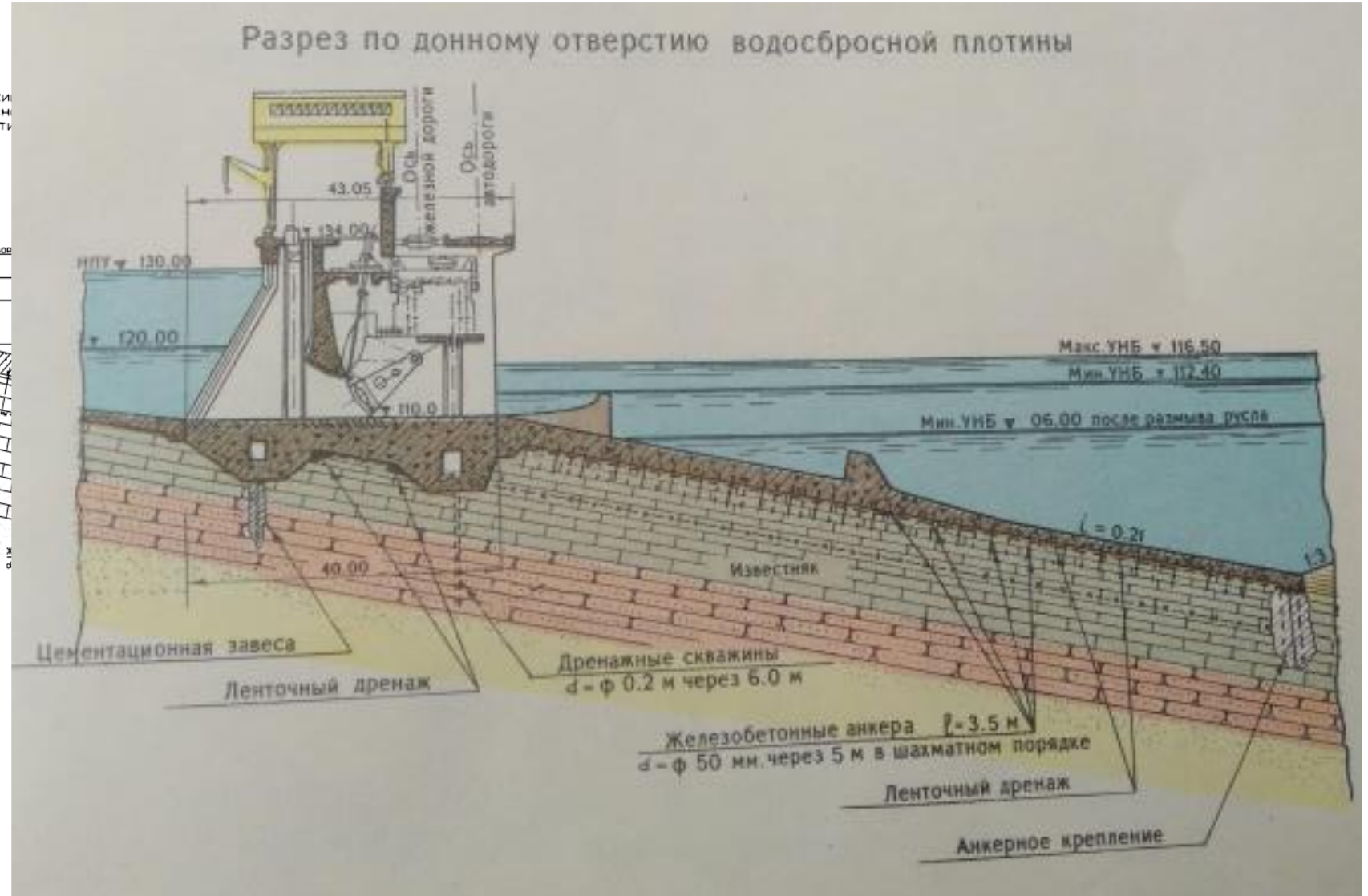
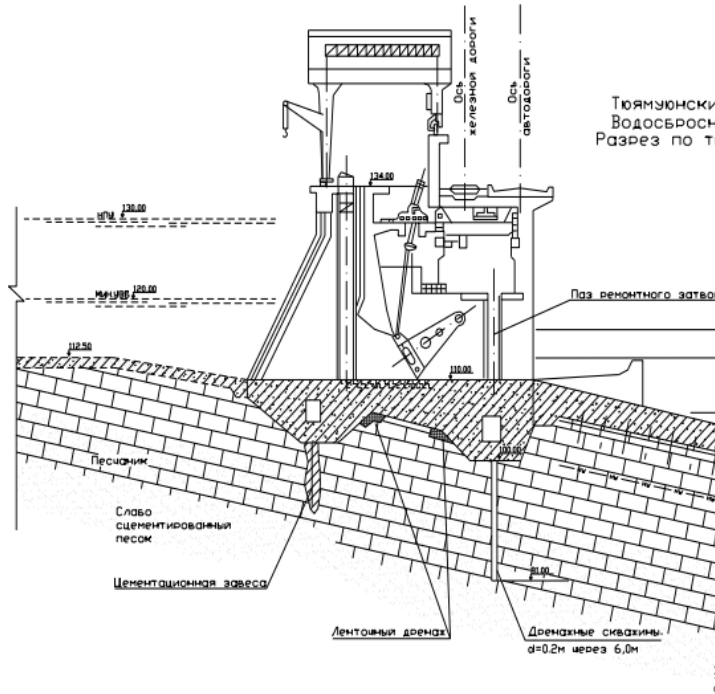
Understanding of the system (6/12)

Spillway and dam



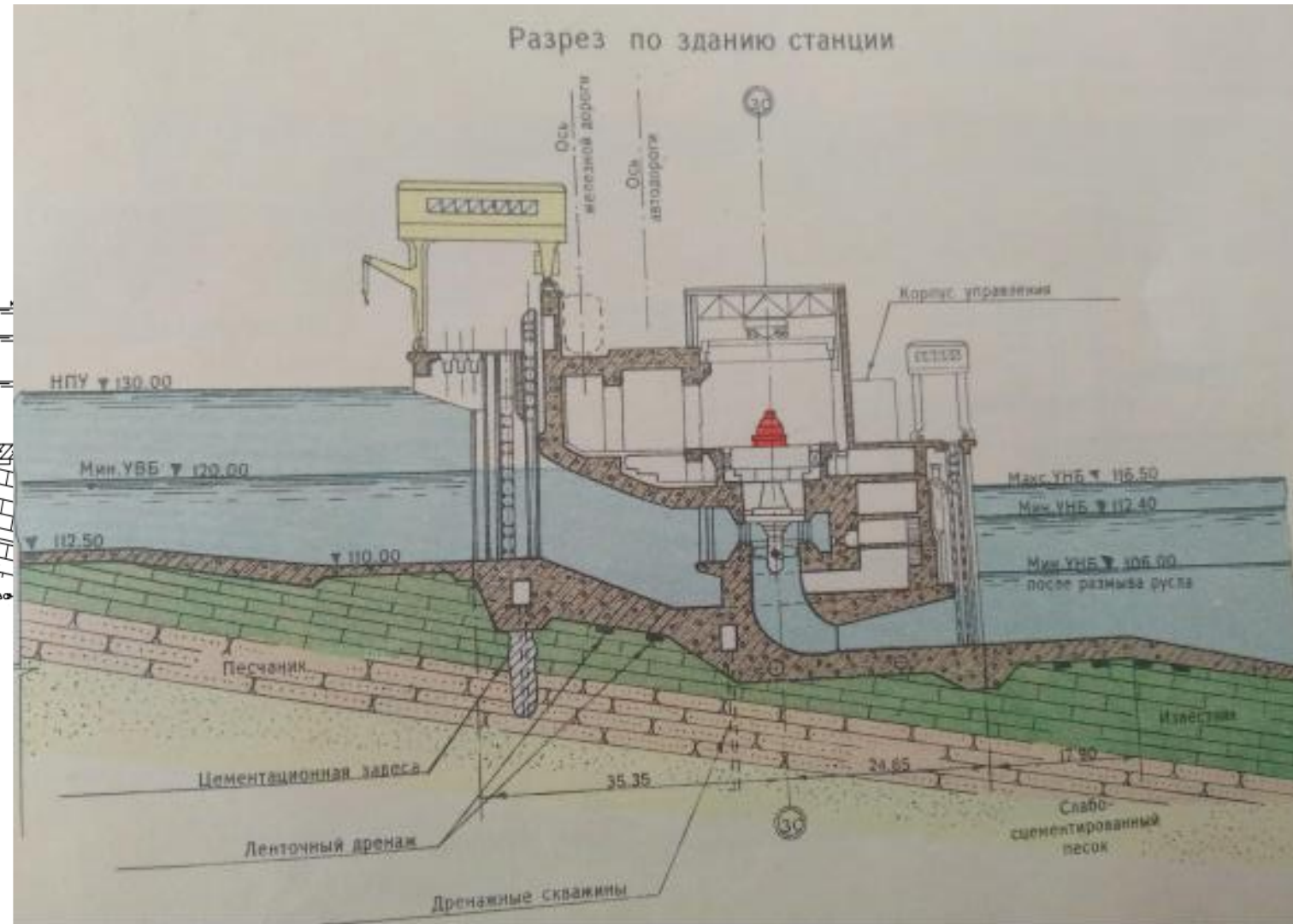
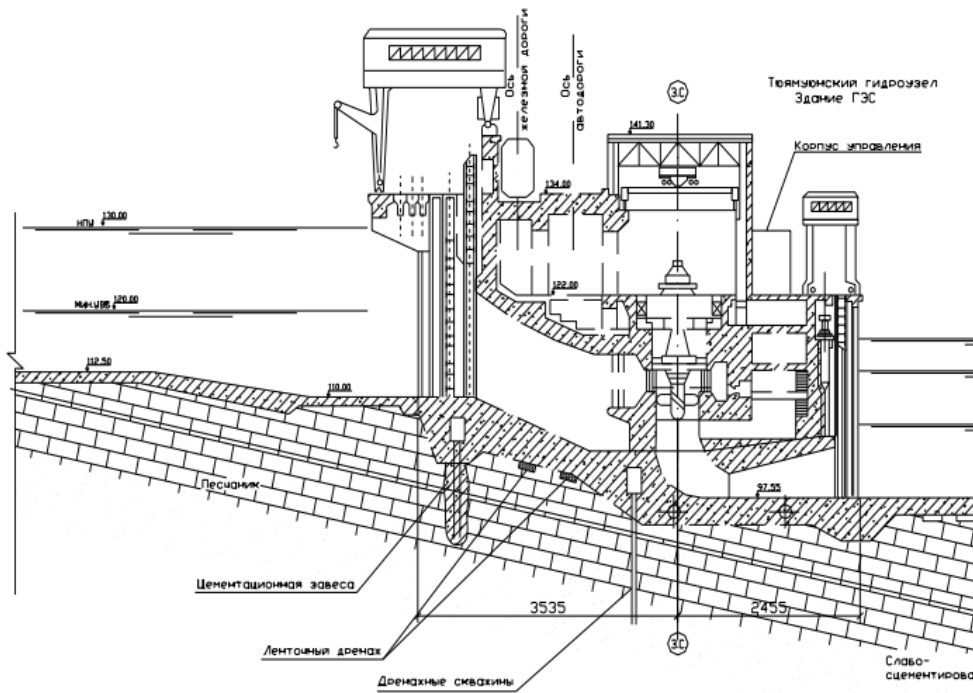
Understanding of the system (7/12)

Undersluice



Understanding of the system (8/12)

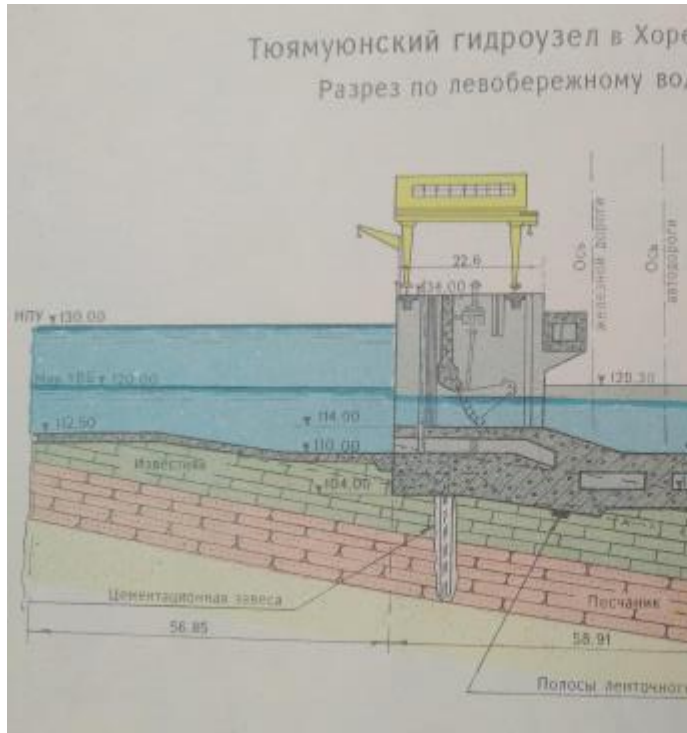
Hydropower intake



Understanding of the system (9/12)

Canal intakes

Тюямуюнский гидроузел в Хорезмской области
Разрез по левобережному водозабору



Разрез по промывным галереям левобережного водозабора




Тюямуюнский гидроузел в Хорезмской области
Разрез по правобережному водозабору

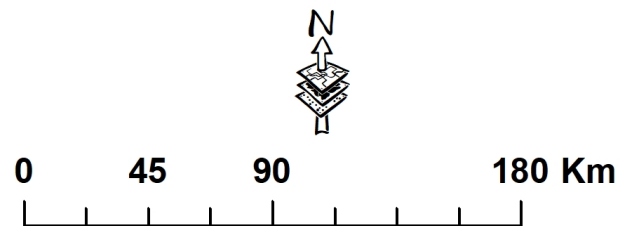


Understanding of the system (10/12)

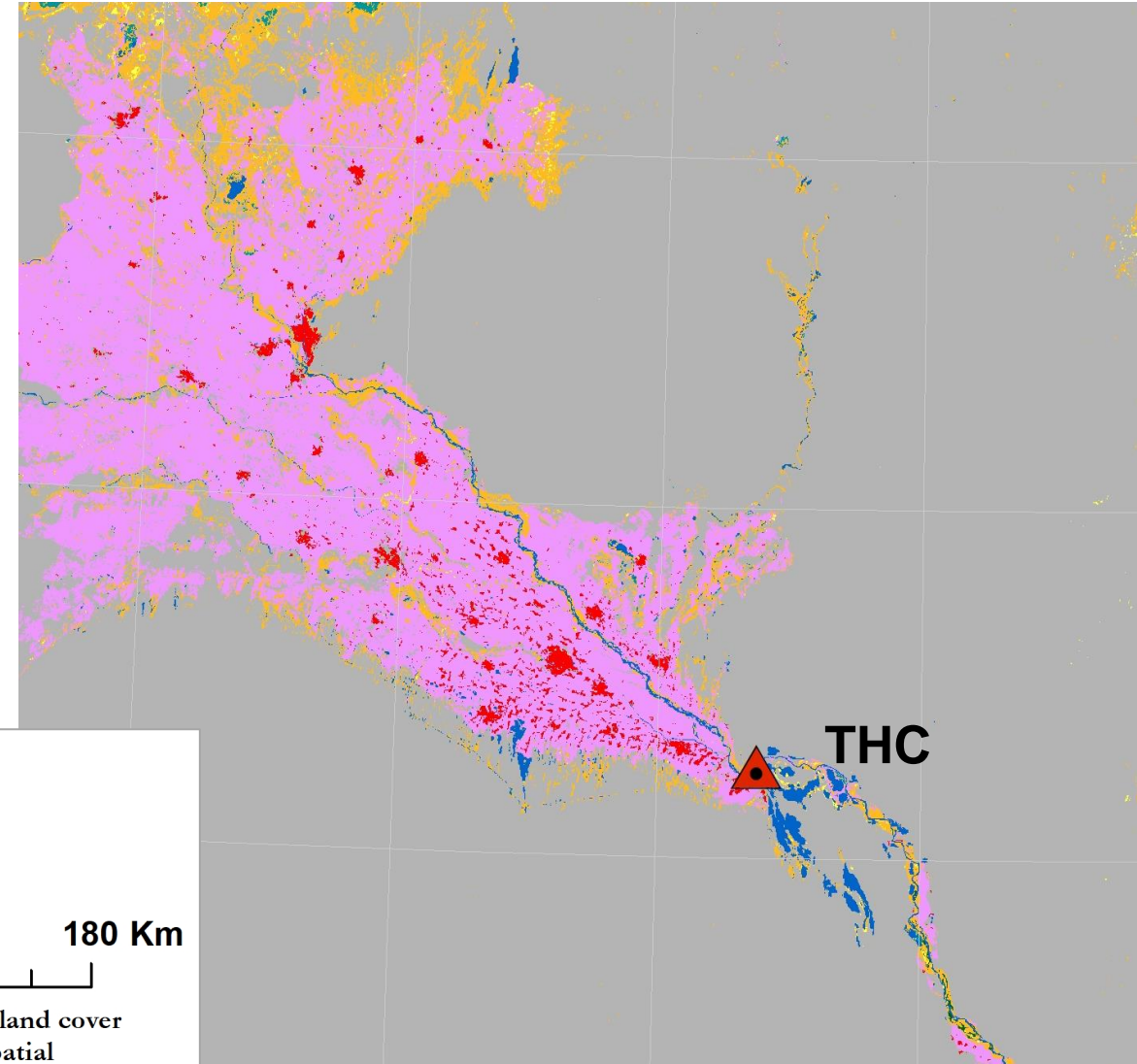
Land use map (2020)

LULC Classes

	Tree cover		Built-up		DAM
	Shrubland		Bare/sparse vegetation		
	Grassland		Permanent water bodies		
	Cropland		Herbacious wetland		



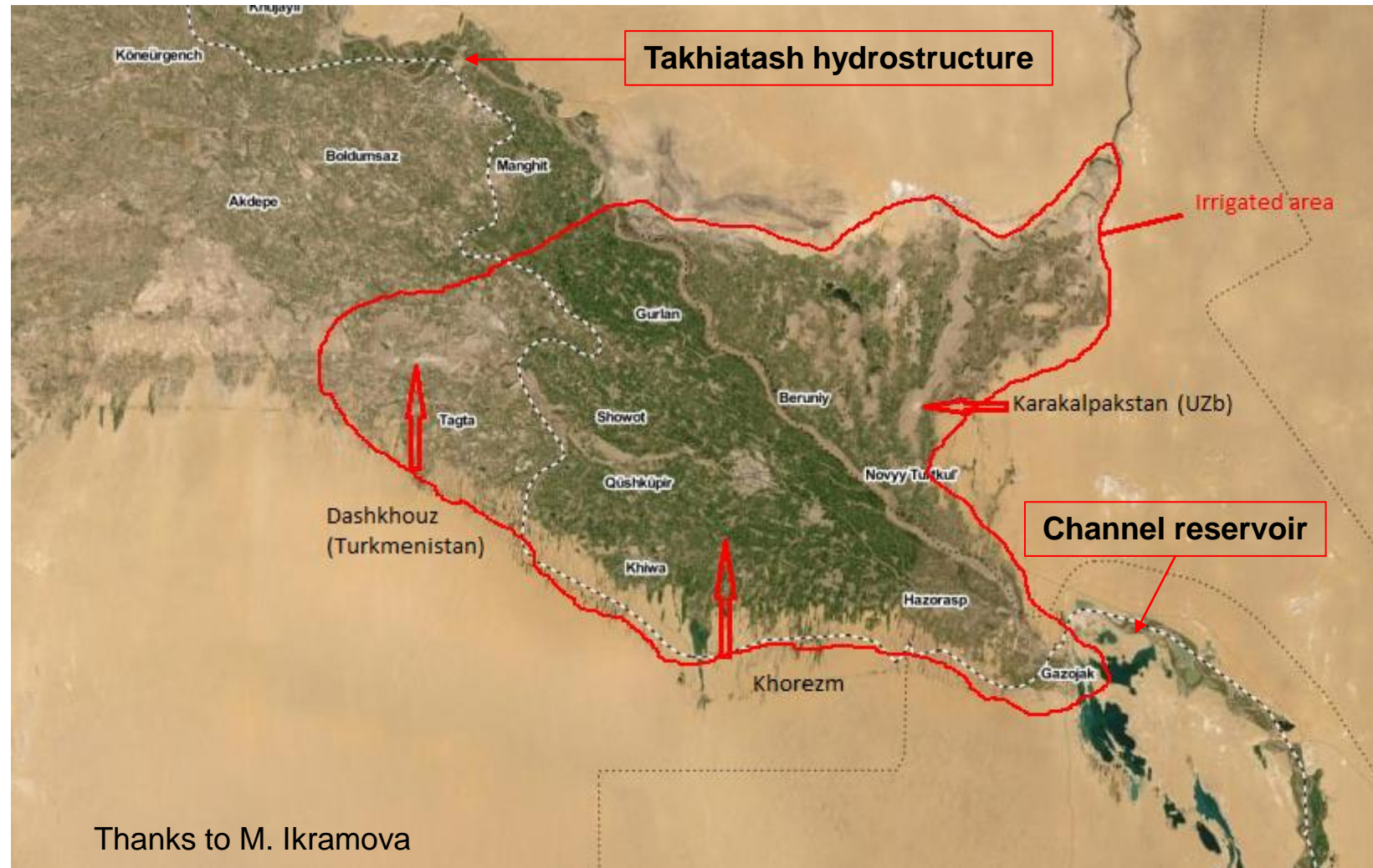
Data Source: Land use and land cover
from ESA with 10m spatial
resolution for year 2020



Understanding of the system (11/12)

Irrigation activities in Uzbekistan and Turkmenistan, served by THC

The THC to Takhiatash along Amu Darya is regulated by the THC, including the irrigated area, namely Khorezm region, Beruni and Turtkul DC (Karakalpakstan) as well as Dashkhouz (Turkmenistan)



Understanding of the system (12/12)

Irrigation activities in Uzbekistan and Turkmenistan, served by THC

Total irrigated area = **751 607** and **273 734** hectares in Uzbekistan and Turkmenistan respectively!

Collectors



Reviewing available data and information (1/3)

On available data and information and their usability

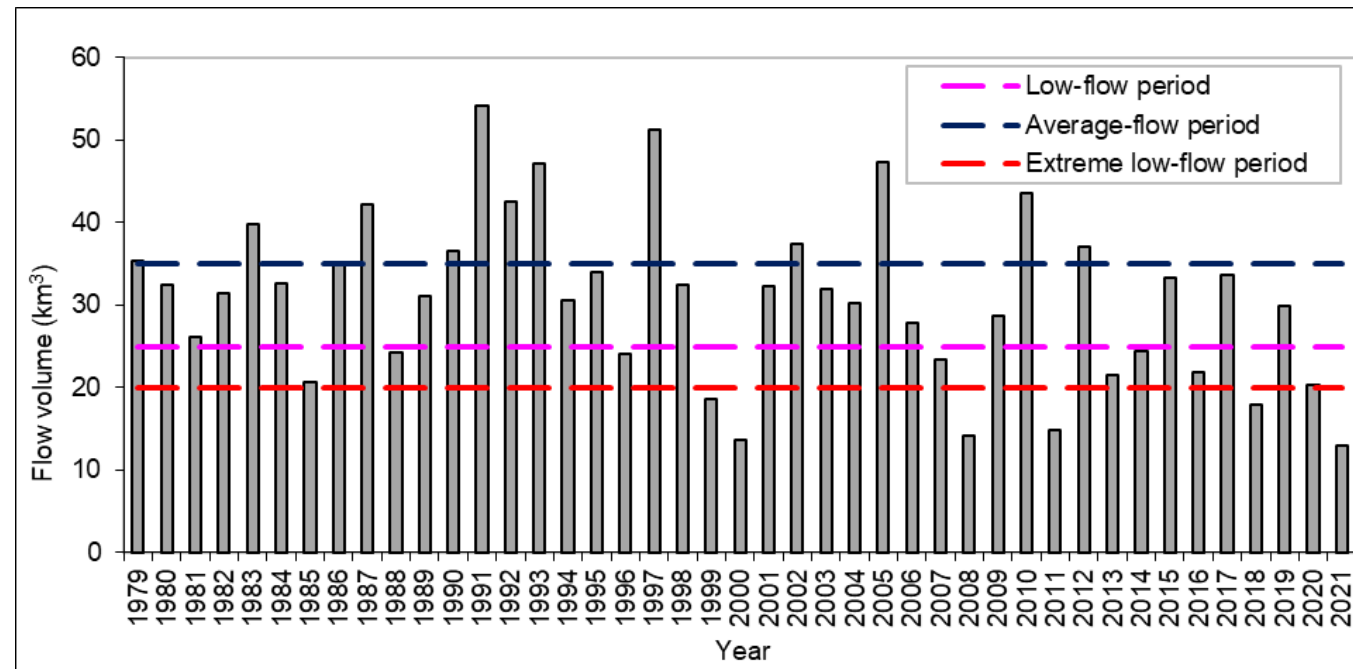
- There are good amount of data and information related to flow and sediment transport that provide system understanding and processes relevant to the problem of THC and Channel reservoir in particular.
- Good measurement and analysis of sediment-induced problems, particularly related to storage loss that provide clear and quantitative idea about the problem.
- Some outcomes require reanalysis to evaluate their consistency.
- These data and analysis are important to prepare sediment removal plan.
- The most important data (physical, mechanical, chemical and biological characteristics of the sediment, deposited in the reservoir) is still missing (there is a 10-year-old measurement of chemical properties, but there could already be quite some changes during this period). This is very important for the selection and analysis of the sediment removal, processing and reuse options and technology. There is an ongoing measurement campaign.

Reviewing available data and information (2/3)

On flow and sediment yield

- Annual flow volumes
- The annual sediment load (**only suspended?!)** approaching the dam:
 - Low-flow year = **30-40 million ton**
 - Average-flow year = **70-90 million ton**
 - High-flow year = 150-170 million ton
 - During average-flow years, the total annual(**check!**) suspended sediment flux is 81.5 million ton, 95% of which occurs during higher flow (snow-melting) period. Whereas, during high-flow years, the annual flux is 129.7 million ton (out of which 122 million ton during snow-melting season)

Annual flow volumes at Darganata (155 km upstream of the dam)



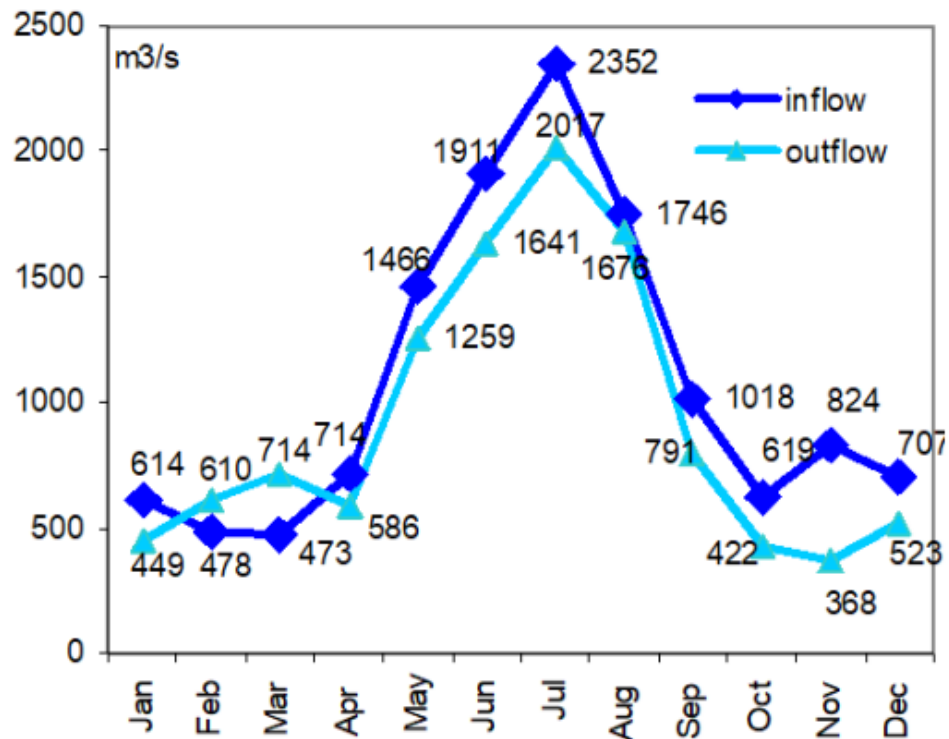
Decreasing trend of annual flow due to upstream withdrawal?

В годы средней водности суммарный объём стока взвешенных наносов в створе Дарганата составляет 81,5 млн. тонн, из которых 95% приходится на половодье; в многоводные годы сток наносов составляет 129,7 млн. тонн, в период половодья – 122,0 млн. тонн.

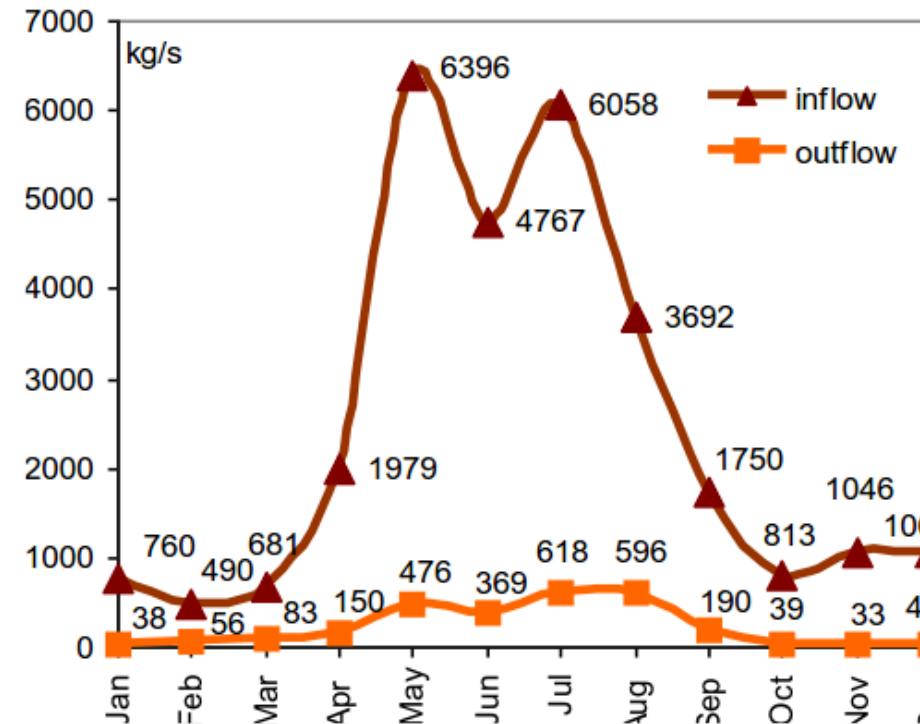
Reviewing available data and information (3/3)

On flow and sediment yield

Inflow at Darganata (155 km upstream of the dam) and outflow at Tuyamuyun (5 km downstream of the dam)



Flow

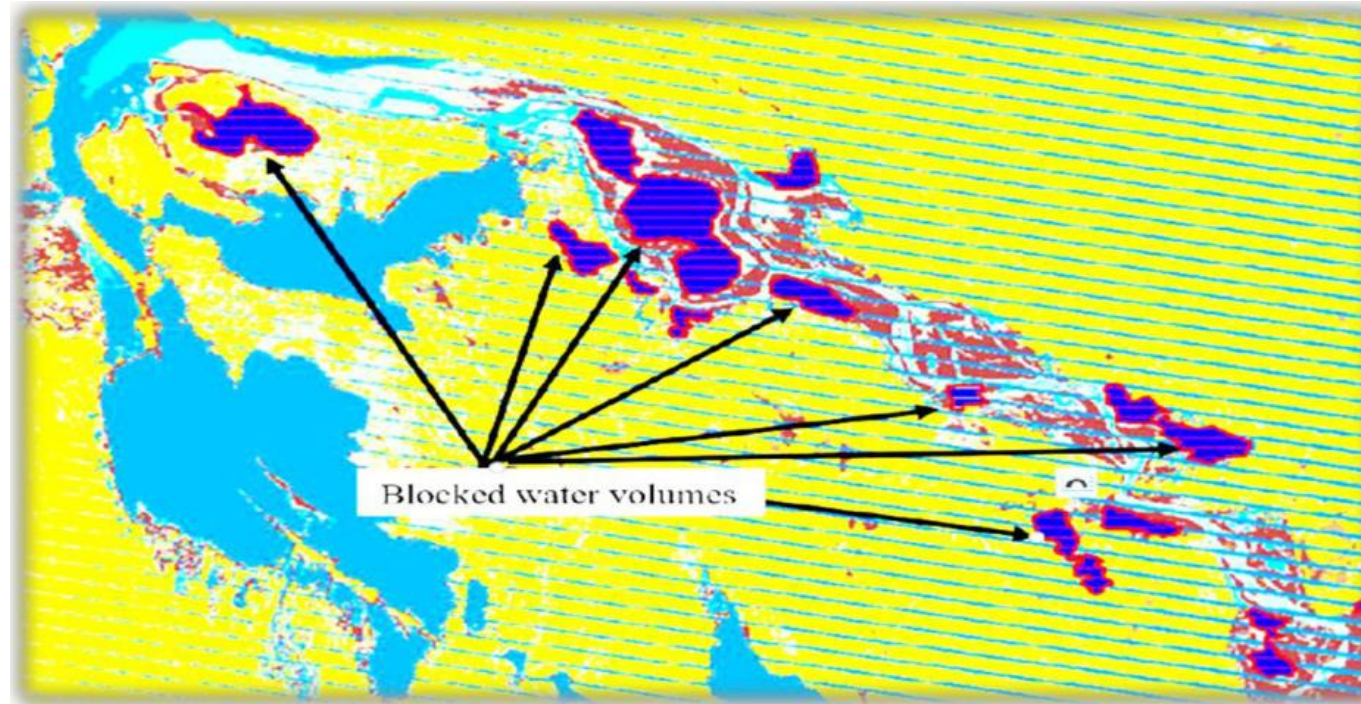


Sediment transport

Assessing magnitude and specifics of the sediment-induced problems at THC (1/11)

Reservoir storage loss - General

- There is a good amount of data and information to quantify storage loss and its feature.
- The dead storage level is 120 m (as live storage data shows zero values below this level).
- The analysis based on 2021 measurement shows the loss of the reservoir volume by 1477 million m^3 (original volume = 2340 million m^3 , whereas current volume = 863 million m^3)



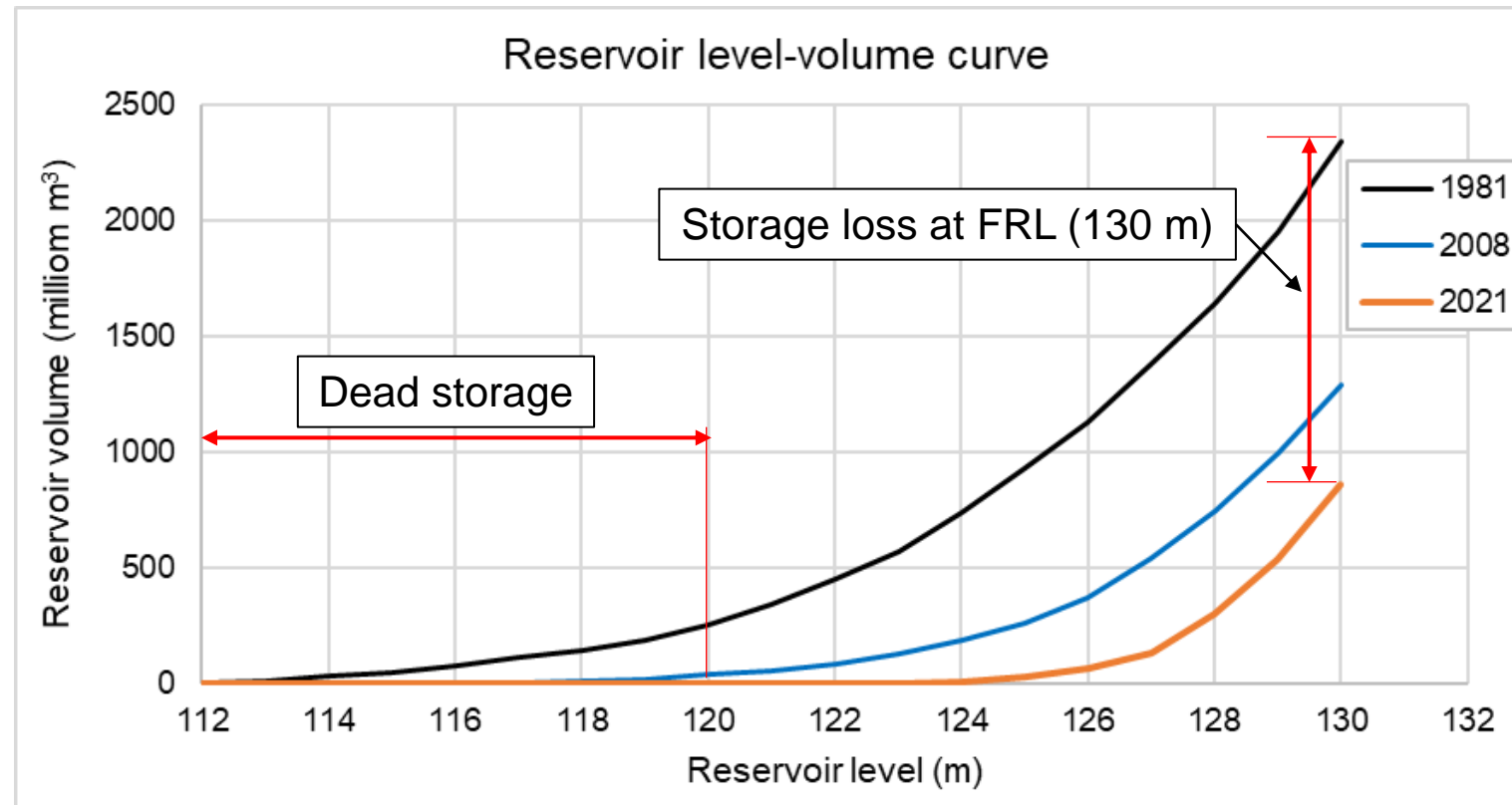
Courtesy: M. Ikramova

Assessing magnitude and specifics of the sediment-induced problems at THC (2/11)

Reservoir storage loss – Vertical variation

Reservoir level – capacity curve reveals followings:

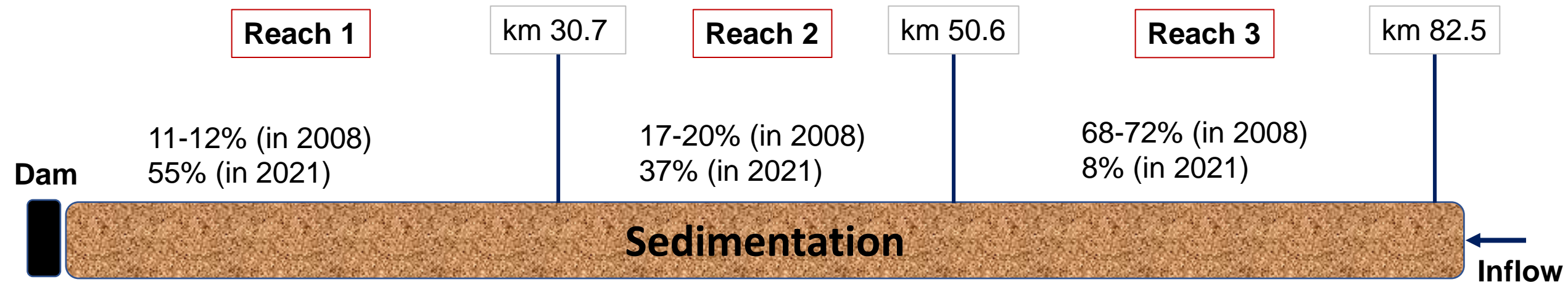
- The storage below the level 125 m is fully lost in 2021, which is about 40% of the total volume (including dead storage which is about 11% of the total volume)
- The storage loss within 125 – 130 m is about 39% of the total loss (i.e. 61% of the total loss occurred below 125 m level).
- The dead storage was almost fully lost already in 2008.



Assessing magnitude and specifics of the sediment-induced problems at THC (3/11)

Reservoir storage loss – Longitudinal variation

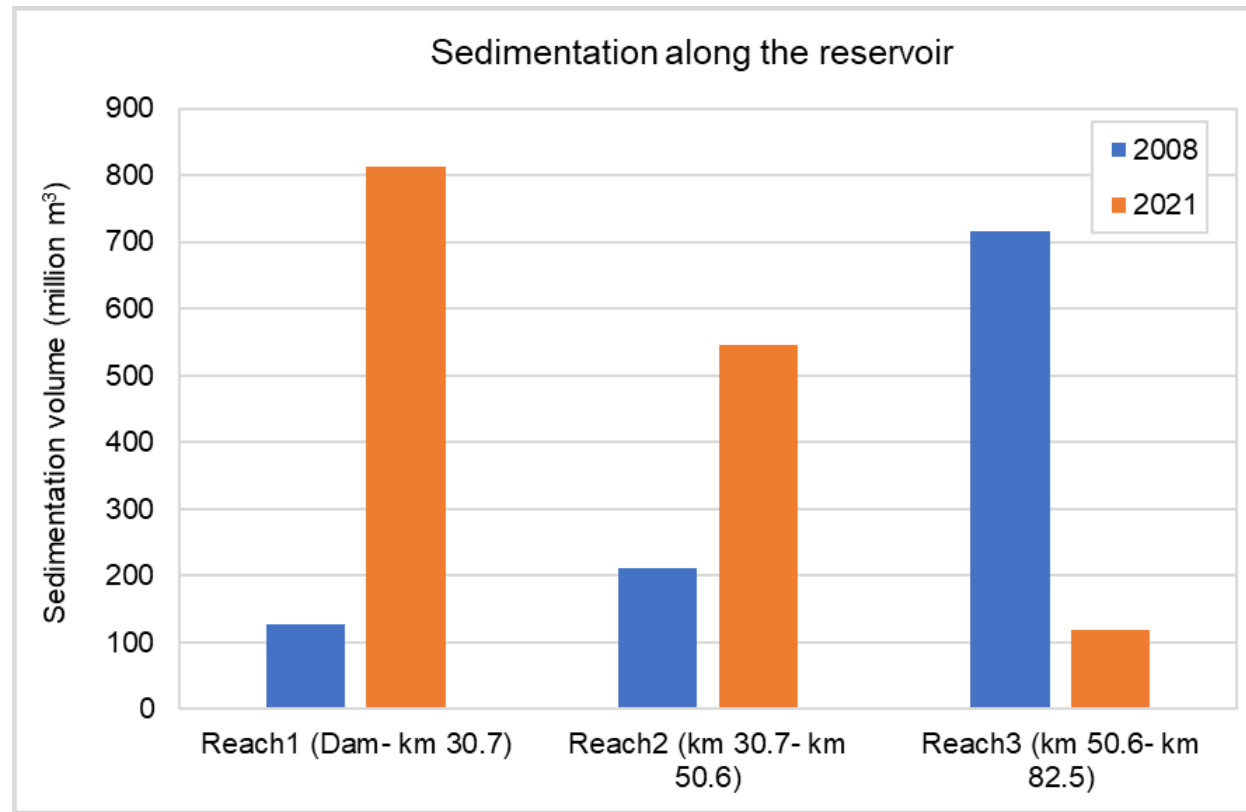
- It is to be noted that the spatial (longitudinal) distribution of sedimentation between 2008 and 2021 differs noticeably showing the propagation of sediment deposition from upstream towards the dam.
- In 2008, 68-72% of deposited volume was in Reach 3 (upstream reach) and only 11-13% in Reach 1 (near the dam). Whereas, in 2021, 55% of deposited volume was in near the dam (and only 8% in Reach 3).



Assessing magnitude and specifics of the sediment-induced problems at THC (4/11)

Reservoir storage loss – Longitudinal variation

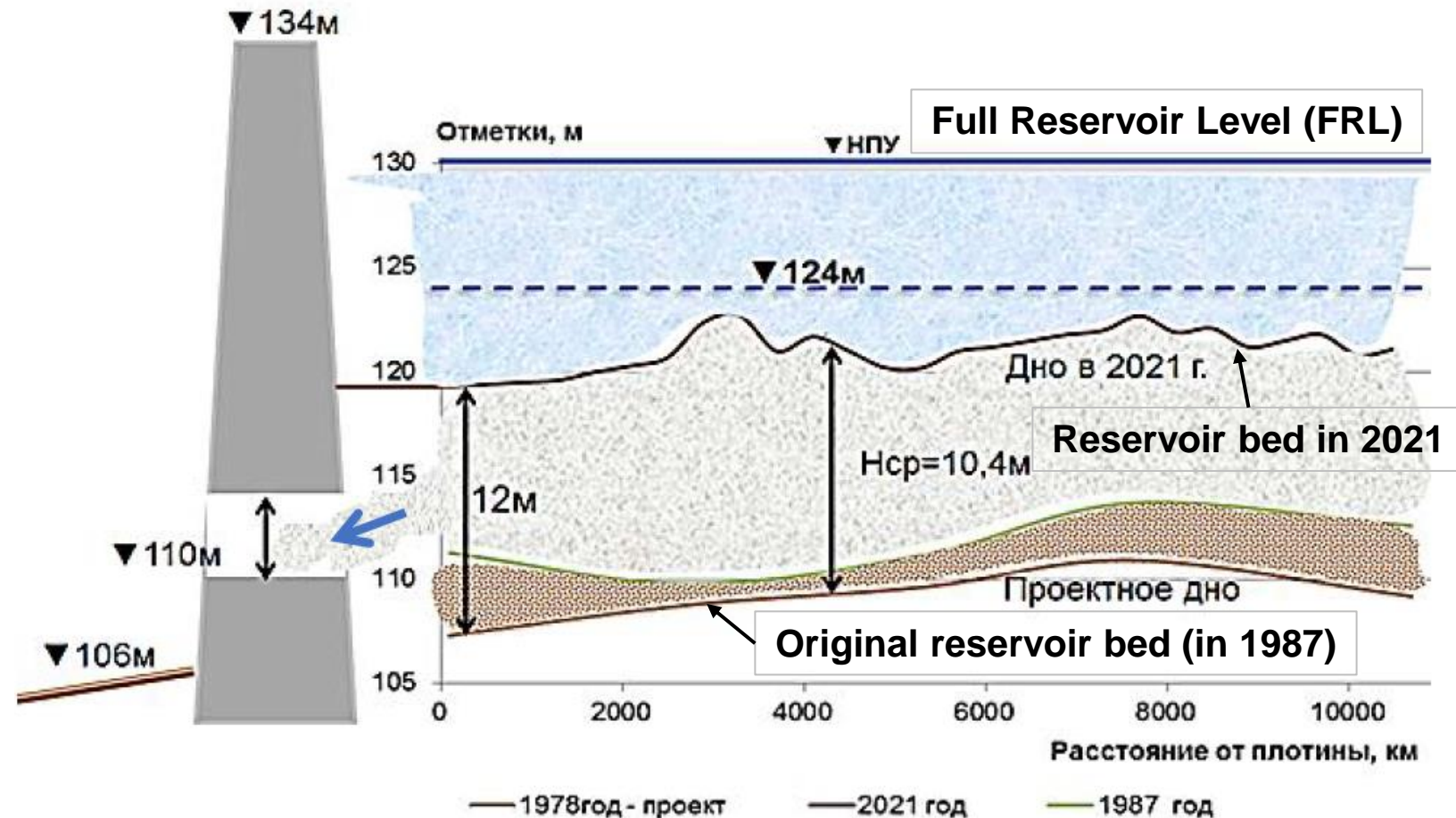
- The plot shows the spatial distribution of sedimentation volume along the reservoir in 2008 and 2021 revealing large volumes near the dam in 2021 (that appears to be moved from the upstream during last 13 years) – 812 million m³ (comparing to 118 million m³ in 2008).
- It is reported that about 79% of the material is deposited within first 40 km upstream of the dam, whereas 21% is deposited within another 40 km reach (in 2021).



Assessing magnitude and specifics of the sediment-induced problems at THC (5/11)

On sedimentation near the dam

As reported, there is about 12 m of deposition layer in front of the hydropower intake (as per 2021 measurement).



Courtesy: M. Ikramova

Assessing magnitude and specifics of the sediment-induced problems at THC (6/11)

Type and characteristic of deposited materials at reservoirs



Assessing magnitude and specifics of the sediment-induced problems at THC (7/11)

Type and characteristic of deposited materials at reservoirs



Assessing magnitude and specifics of the sediment-induced problems at THC (8/11)

Type and characteristic of deposited materials at reservoirs



Assessing magnitude and specifics of the sediment-induced problems at THC (9/11)

Type and characteristic of deposited materials at reservoirs



Assessing magnitude and specifics of the sediment-induced problems at THC (10/11)

Type and characteristic of deposited materials at reservoirs



Assessing magnitude and specifics of the sediment-induced problems at THC (11/11)

Chemical analysis

Indicated values for salinity and metals are acceptable to consider the materials clean, however:

- ✓ The data is 10 years old.
- ✓ No information on number of samples taken, which depth and the top 5% values to evaluate the accuracy.

№	Component	Component content				Component content in %			
		in sediments, g/kg		in water, mg/l		in sediments		in water	
		marginal	avg.	marginal	average	marginal	avg.	marginal	avg.
1.	Salinity	1.3-1.9	1.6	700-1600	1000	0.13-0.19	0.16	0.07-0.16	0.10
2.	COD	16-27	19	14.0-3.2	20.4	1.6-2.7	1.9	0.001-0.003	0.002
3.	total nitrogen	1.8-2.4	2.1	0.33-1.28	0.41	0.18-0.24	0.21	0.3-1.3 10^{-4}	0.4 10^{-4}
4.	Phosphates (according to P)	0.1-0.5	0.4	0-0.05	0.01	0.01-0.05	0.04	0-0.5 10^{-5}	0.1 10^{-5}
5.	surfactant	0.03-0.2	0.1	0.01-0.03	0.02	0.003-0.02	0.01	0.1-0.3 10^{-5}	0.2 10^{-5}
6.	Oil products	0.01-0.3	0.17	0-0.04	0.02	0.001-0.03	0.02	0-0.4 10^{-5}	0.2 10^{-5}
7.	Phenols	0.001-0.02	0.012	0.001-0.004	0.003	0.1-2 10^{-3}	1.2 10^{-3}	0.1-0.4 10^{-5}	0.3 10^{-5}
8.	Alpha HCH, mg/kg	0.03-0.06	0.04	0-2.6 10^{-5}	1.0 10^{-5}	0.3-0.6 10^{-5}	0.4 10^{-5}	0-2.6 10^{-9}	1.0 10^{-9}
9.	Gamma HCCH, mg/kg	0.001-0.02	0.01	0-1.4 10^{-5}	1.0 10^{-5}	0.1-2 10^{-3}	1.0 10^{-3}	0-1.4 10^{-9}	1.0 10^{-9}
10.	DDT, mg/kg	0.0		0.0		0	0	0	0
11.	Iron, g/kg	0.10-0.30	0.18	0.01-0.03	0.02	0.01-0.03	0.02	0.1-0.3 10^{-5}	0.2 10^{-5}
12.	Copper, mg/kg	2.6-16.2	6.3	0.001-0.007	0.003	2.6-16 10^{-4}	6.3 10^{-4}	0.1-0.7 10^{-6}	0.3 10^{-6}
13.	Zinc, mg/kg	5.0-11.2	9.1	0-0.003	0.0015	5-11 10^{-4}	9.1 10^{-4}	0-0.3 10^{-6}	0.2 10^{-6}
14.	Molybdenum, mg/kg	7.3-31.0	17.2	-	-	7-31 10^{-4}	17 10^{-4}	-	-
15.	Lead, mg/kg	7.2-23.2	11.3	0-27 10^{-3}	9.3 10^{-3}	7-23 10^{-4}	17 10^{-4}	0-27 10^{-7}	9.3 10^{-7}
16.	Manganese, mg/kg	.01-0.20	0.04	-	-	0.1-2 10^{-5}	0.4 10^{-5}	-	-
17.	Chromium 6+, mg/kg	1.0-3.2	2.1	0-1.4 10^{-3}	0.37 10^{-3}	1-3 10^{-4}	2.1 10^{-4}	0-1.4 10^{-7}	3.7 10^{-8}
18.	Chromium 3+, mg/kg	0.4-3.1	1.3	0-0.5 10^{-3}	0.17 10^{-3}	0.4-3 10^{-4}	1.3 10^{-4}	0-0.5 10^{-7}	1.7 10^{-8}
19.	Mercury, mg/kg	.1-0.42	0.26	0-0.3 10^{-3}	17 10^{-3}	0.1-0.4 10^{-4}	0.3 10^{-4}	0-0.3 10^{-7}	1.7 10^{-7}

Part 2

**Screening of the possible technical measures
based on the review and global practices**

Management of sediment induced problems considering beneficial reuse

General practices on managing sediment-induced problems in reservoirs (1/13)

Type of problems



Magnitude of problems



Source of problems



Reasons of problems

Natural or/and human-induced, e.g. mismanagement

Sediment Problem

Medium/High/Extreme

Low

Management of Sediment-Induced Problems

Screening & Analyzing Options & Technologies

Structural (Soft/Hard)

Recurrent

Non-Structural

Sediment Reuse & Circular Benefit

Feasibility & Impact Assessment

Soft/Non-Structural/
No-Regret
Measures

Criteria

Safety

Water Security

Technical

Social

Environmental

Economic

Legal

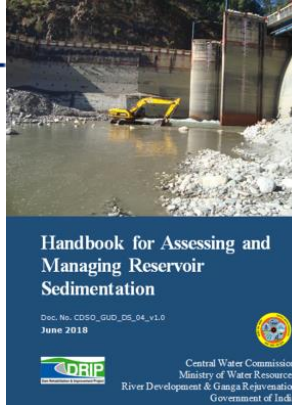
Designing & Implementing Sediment Management Program

Regular Monitoring & Assessment of Sediment Management Performance

Reservoir Morphology Information System (RMIS)

Integrating in DHARMA

Revision & Adaptation of Sediment Management Program (IF REQUIRED)



Giri et al. (2019)

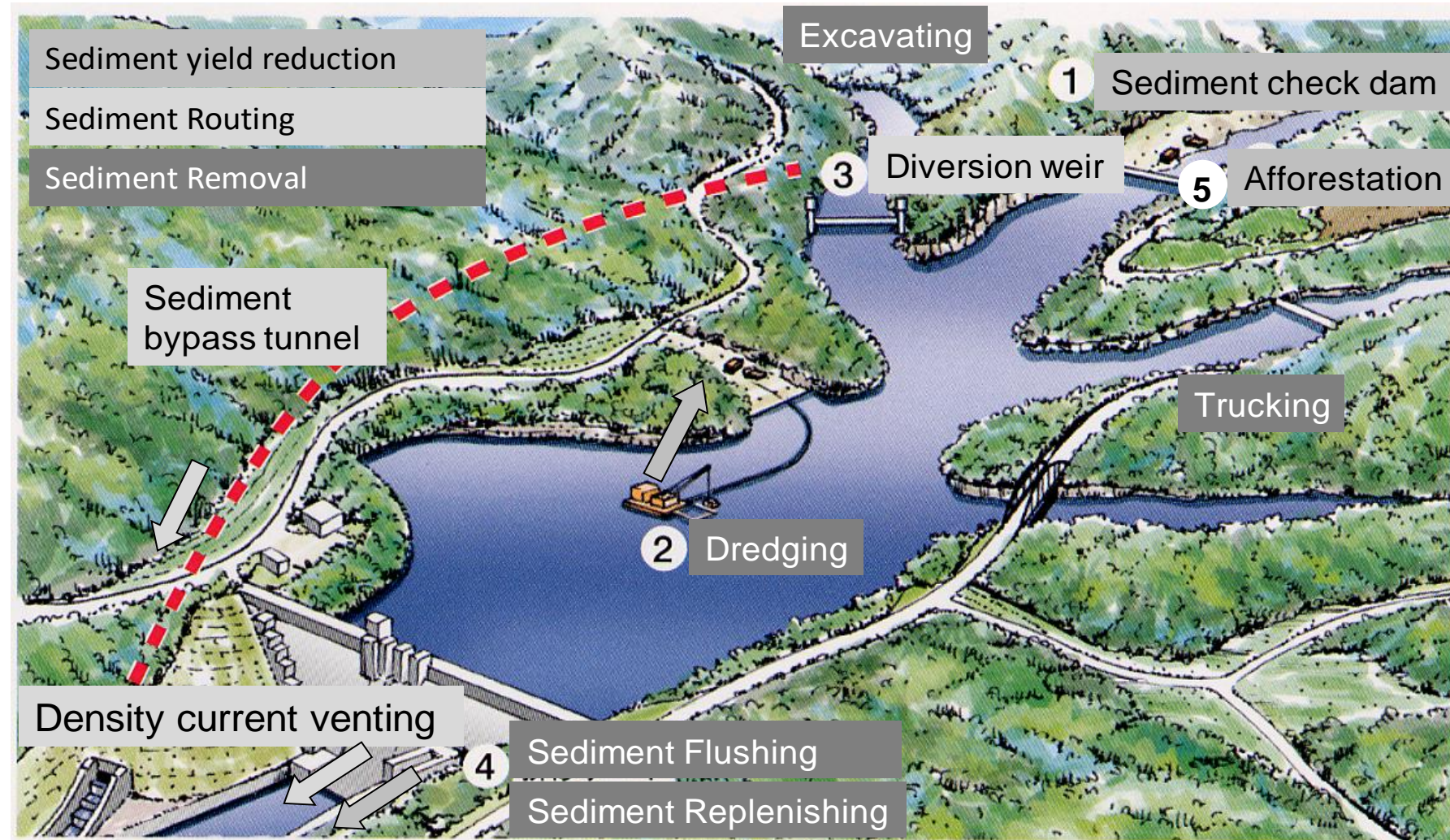
Asset Management Tool, developed under dam safety project in India

General practices on managing sediment-induced problems in reservoirs (2/13)

Sediment yield reduction
(catchment/land-use/river management)

Sediment routing

Sediment removal or redistribution



Source: Japan paper

General practices on managing sediment-induced problems in reservoirs (3/13)

Shihmen reservoir (Taiwan)

Existing and proposed sediment management measures in Shihmen reservoir and expected results of their implementation

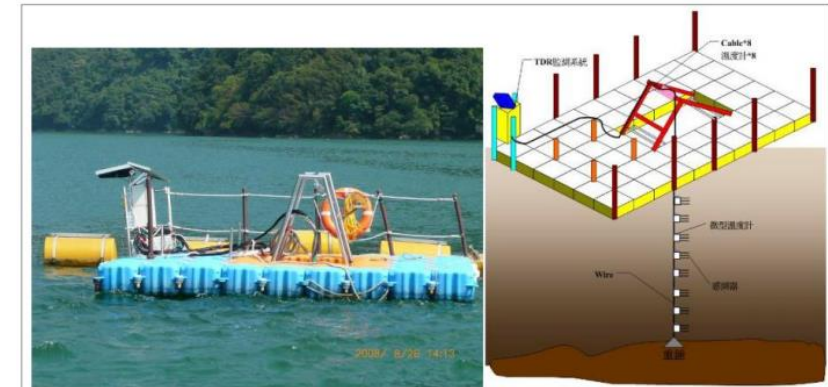
Average annual sediment inflow (10 ⁶ m ³)	Expected average annual sediment outflow						Unit: 10 ⁶ m ³
	PRO sluice way	Power plant penstock renovation	Dawanping silt sluice tunnel	Amuping sediment sluice tunnel	Dedging near dam	Dredging u/s from reservoir	
3.42	0.15 (4%)	1.02 (30%)	0.71 (21%)	0.64 (19%)	0.50 (15%)	0.40 (12%)	3.42
		55%		19%	26%		100%

Gated sediment sluice tunnels

- **FEWS** may help optimal gate operation



Real-time measurement of sediment concentration using Time Domain Reflectometry (TDR)



Chung and Lin (2011)

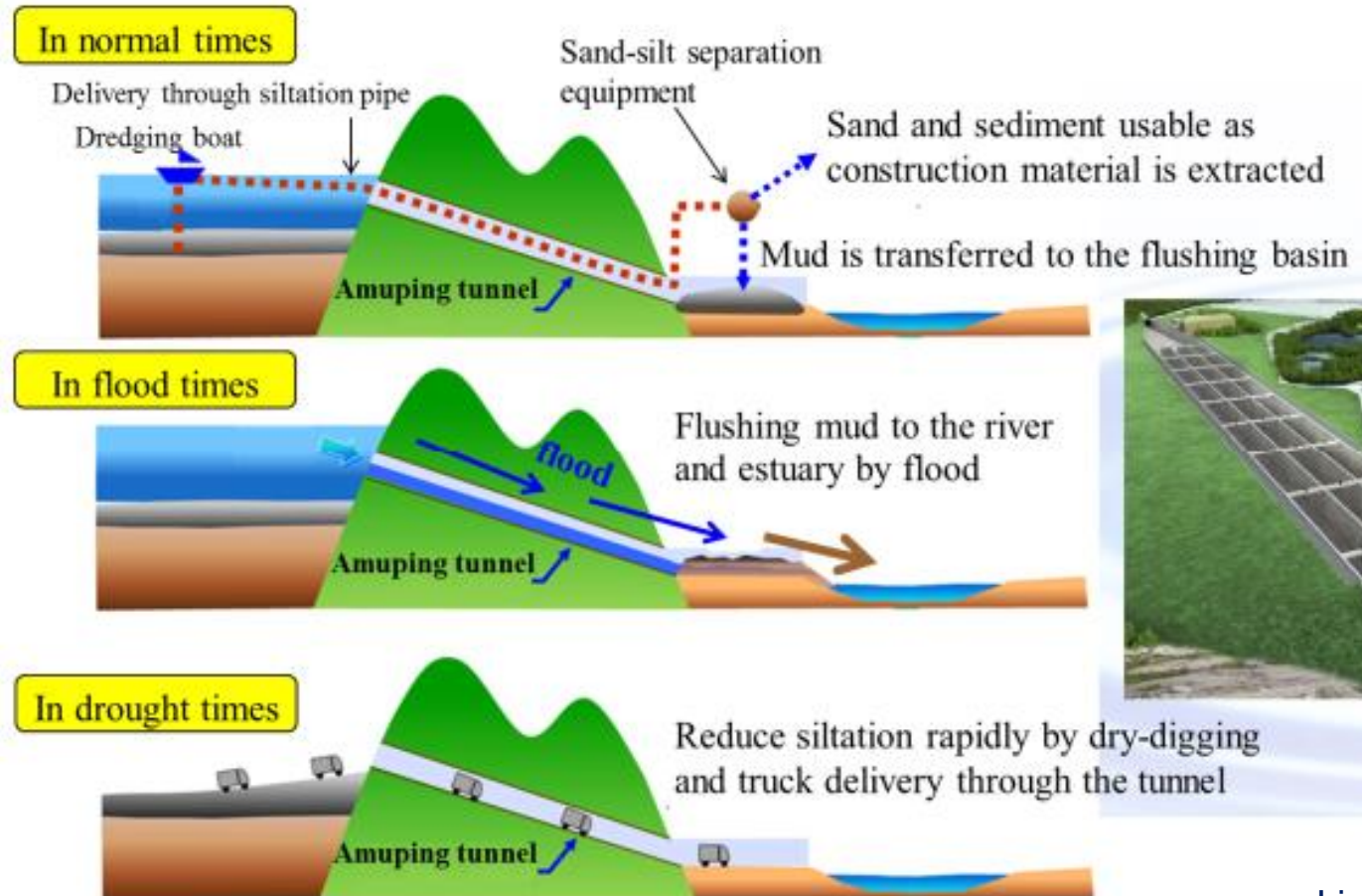
General practices on managing sediment-induced problems in reservoirs (4/13)

Shihmen reservoir (Taiwan)

Muddy reservoir during typhoon



Multifunctional desilting tunnel

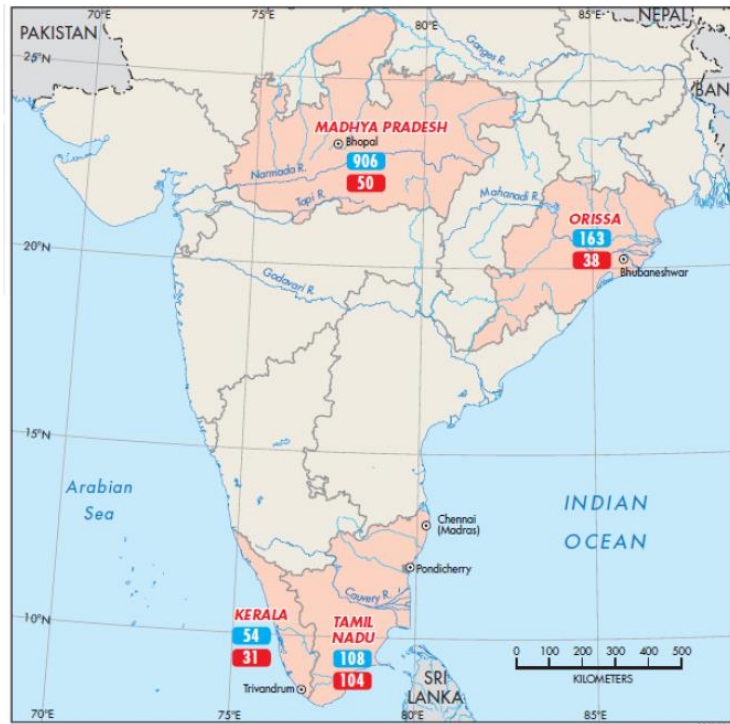


General practices on managing sediment-induced problems in reservoirs (5/13)

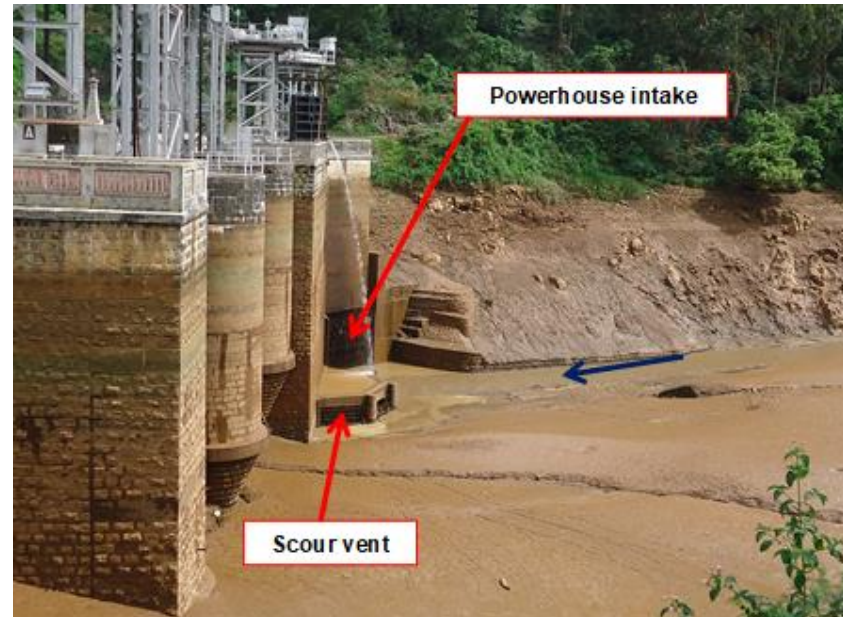
Dam Rehabilitation and Improvement Program - DRIP (India)

More than 5000 large dams in India

Rehabilitation of > 250 dams
and reservoirs in 7 States



Kunda Palam (Tamil Nadu)



Pillur (Tamil Nadu)



Maneru Bhali – 1
(Uttarakhand)

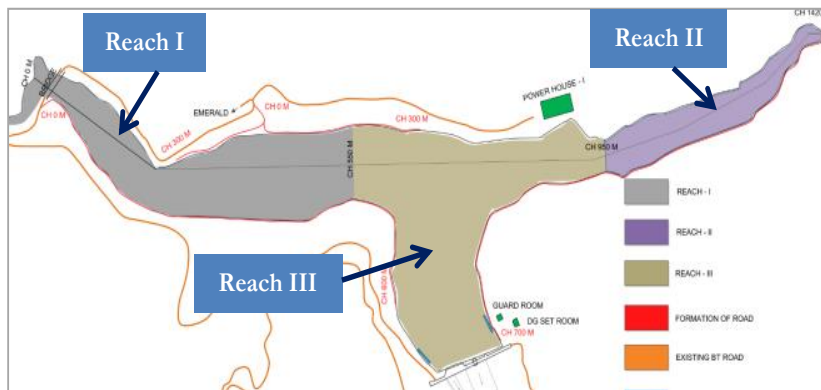


General practices on managing sediment-induced problems in reservoirs (6/13)

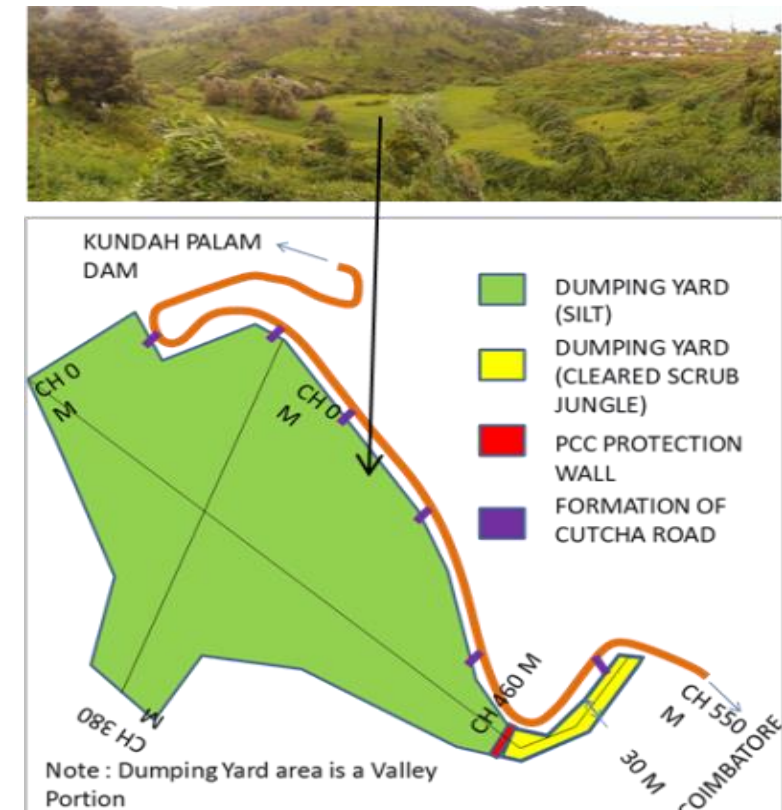
Dam Rehabilitation and Improvement Program - DRIP (India)

Sediment management with removal and land filling

Sediment removal plan



Sediment reuse plan



Vegetated deposits at upstream of Reach I



Deeper channel, approaching to tunnel intake (Reach III)



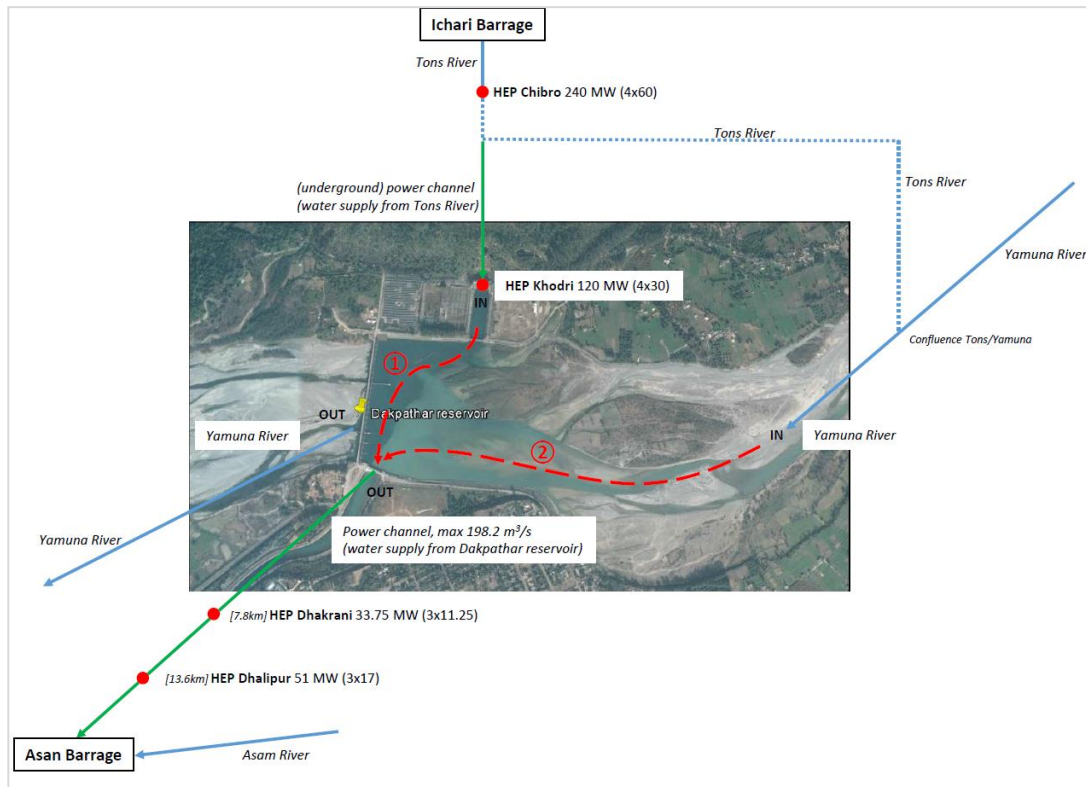
General practices on managing sediment-induced problems in reservoirs (7/13)

An integrated approach to sediment management - A pilot case of Dakpathar barrage (India)

Data collection, field measurement and analysis



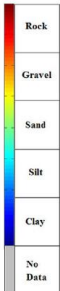
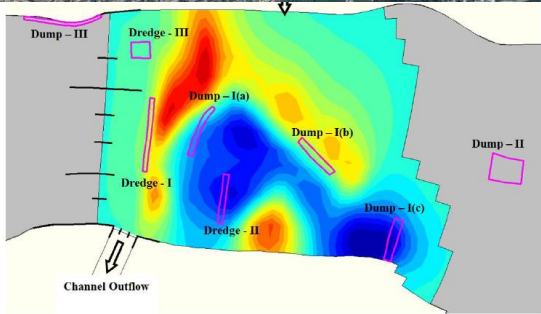
Deltares



General practices on managing sediment-induced problems in reservoirs (8/13)

An integrated approach to sediment management - A pilot case of Dakpathar barrage (India)

Screening and analysis of dredging options (morphological modelling)



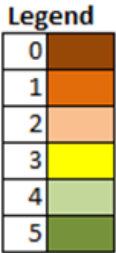
Average water depth

Location	Water Depth (m)
Dredge - I	2.8
Dredge - II	1.42
Dredge - III	3.45
Dump - I(a)	1.62
Dump - I(b)	1.64
Dump - I(c)	1.55
Dump - II	0.00
Dump - III	1.00

Distances between Dredging and Dumping areas

From / To	Dump - I(a)	Dump - I(b)	Dump - I(c)	Dump - II	Dump - III
Dredge - I	120 m	425 m	850 m	890 m	350 m
Dredge - II	180 m	255 m	435 m	710 m	585 m
Dredge - III	250 m	510 m	780 m	950 m	215 m

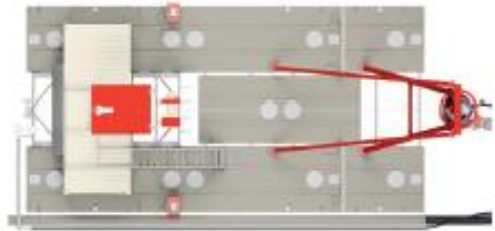
Criteria	Dredge-I	Dredge-II	Dredge-III
distance to the dumping locations	5	4	3
water depth	4	2	4
Turbidity	3	3	4
availability of Sand	4	1	4
less suspended sediment to the power channel	3	3	4
increase total storage	4	4	4
increase live storage	1	1	1
Total	24	18	24
Total rating	3.4	2.6	3.4



General practices on managing sediment-induced problems in reservoirs (9/13)

An integrated approach to sediment management - A pilot case of Dakpathar barrage (India)

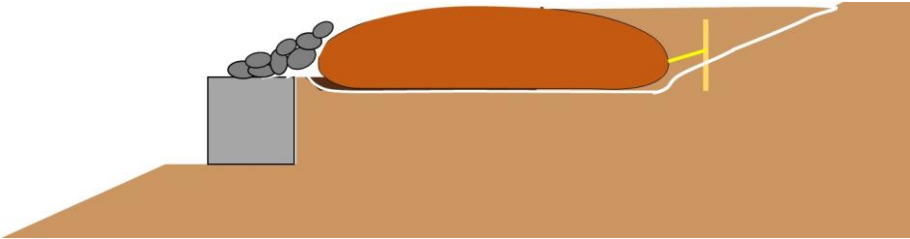
Selection of dredging equipment and execution



General practices on managing sediment-induced problems in reservoirs (10/13)

An integrated approach to sediment management - A pilot case of Dakpathar barrage (India)

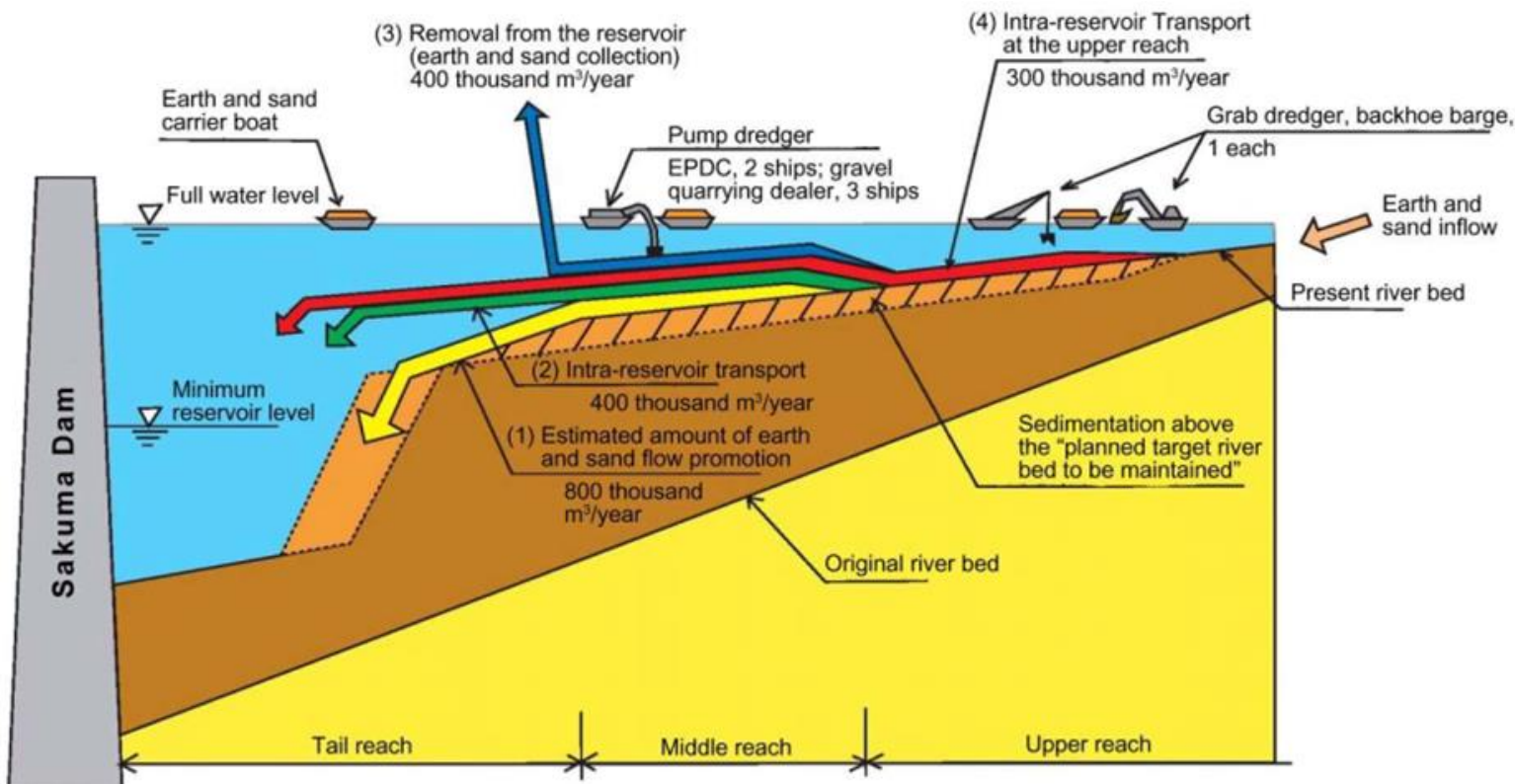
Geotube filling and used for bank protection downstream



General practices on managing sediment-induced problems in reservoirs (11/13)

Sakuma reservoir (Japan)

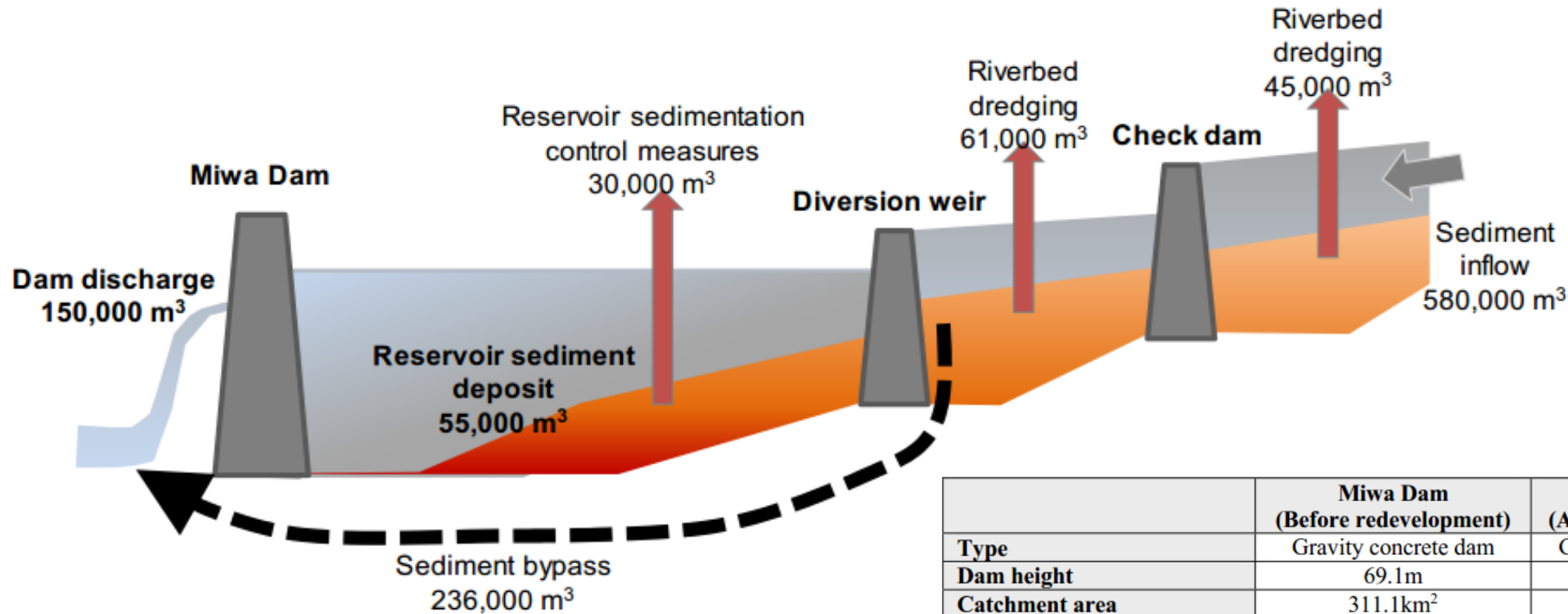
Sediment management with beneficial reuse (replenishment for habitat suitability and reuse as construction materials)



General practices on managing sediment-induced problems in reservoirs (12/13)

Miwa reservoir (Japan)

Average inflow and outflow of sediments (with sediment management)

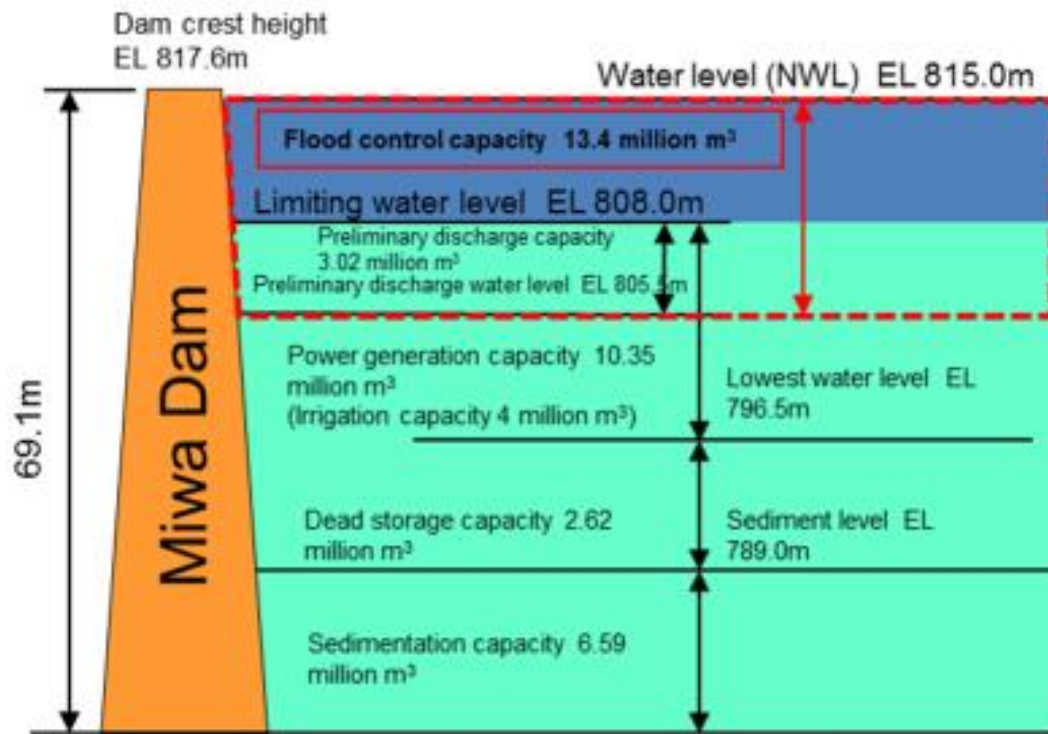


	Miwa Dam (Before redevelopment)	Miwa Dam (After redevelopment)	Difference
Type	Gravity concrete dam	Gravity concrete dam	
Dam height	69.1m	69.1m	
Catchment area	311.1km ²	311.1km ²	
Total reservoir capacity	29.95 million m ³	29.95 million m ³	
Flood control capacity	13.40 million m ³	16.20 million m ³	2.8 million m ³ increase
Water utilization capacity *	10.35 million m ³	7.55 million m ³	2.8 million m ³ increase

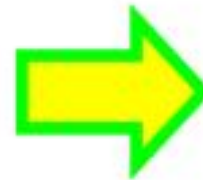
General practices on managing sediment-induced problems in reservoirs (13/13)

Miwa reservoir (Japan)

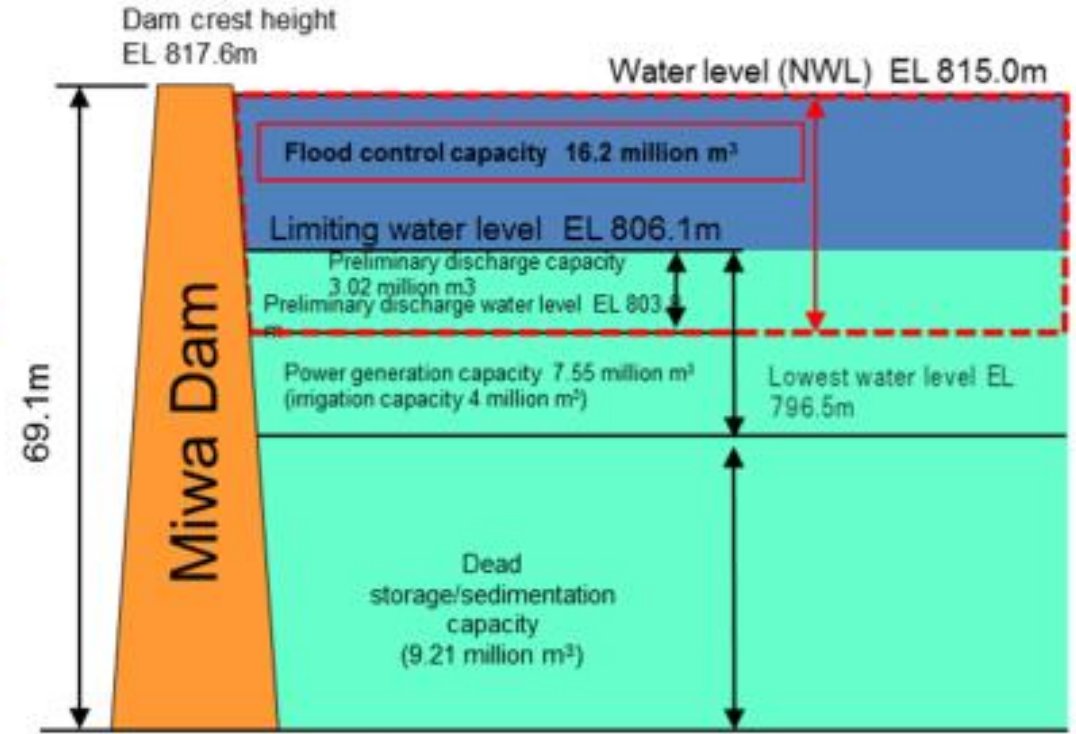
Change in the allocation of reservoir capacity



<Allocation of reservoir capacity before redevelopment>



Water utilization capacity of 2.8 million m³ to be transferred to flood control capacity



<Allocation of reservoir capacity after redevelopment>

Practices on beneficial reuse of sediment (1/19)

Sediment management considering beneficial reuse

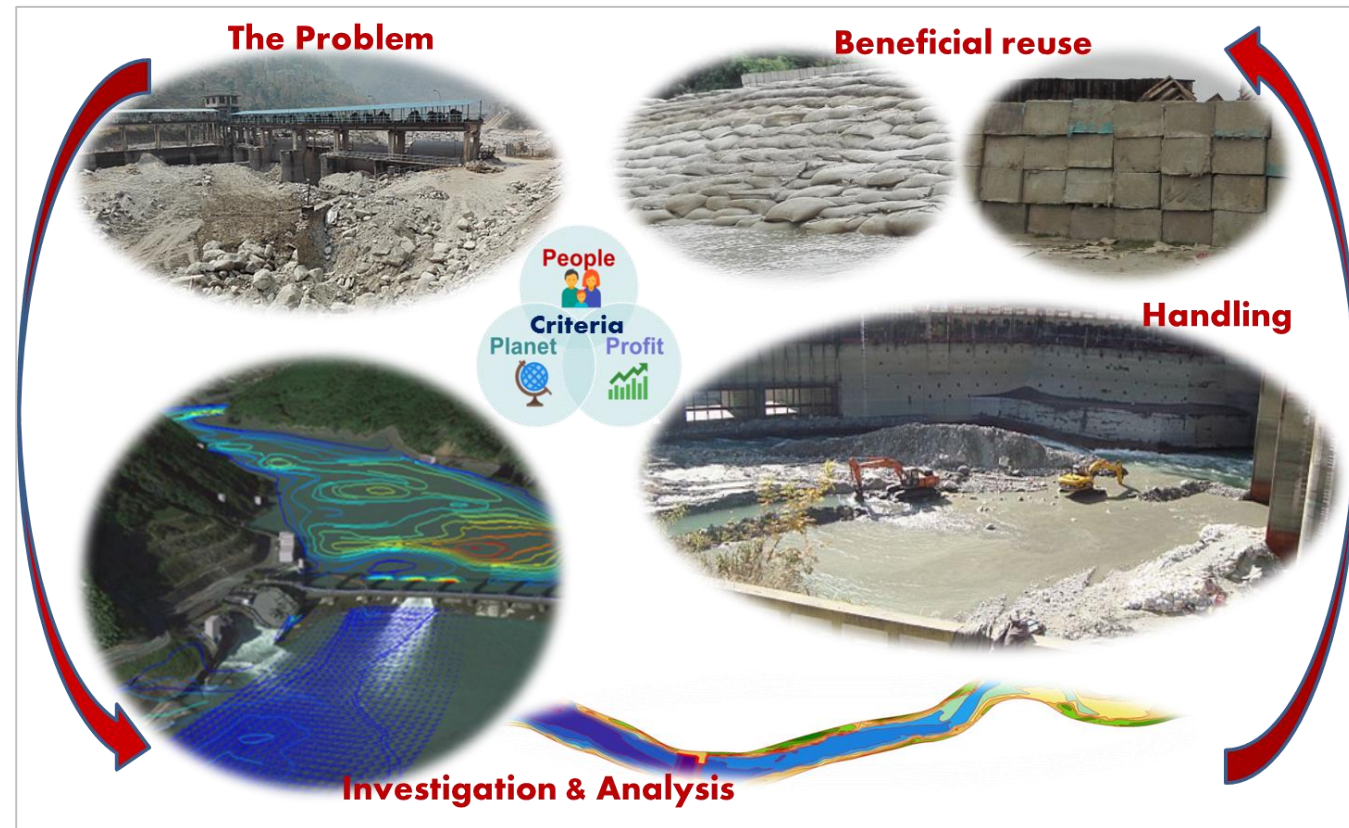
Problem to Opportunity



- Engineering uses
- Agricultural/product uses
- Environmental enhancement

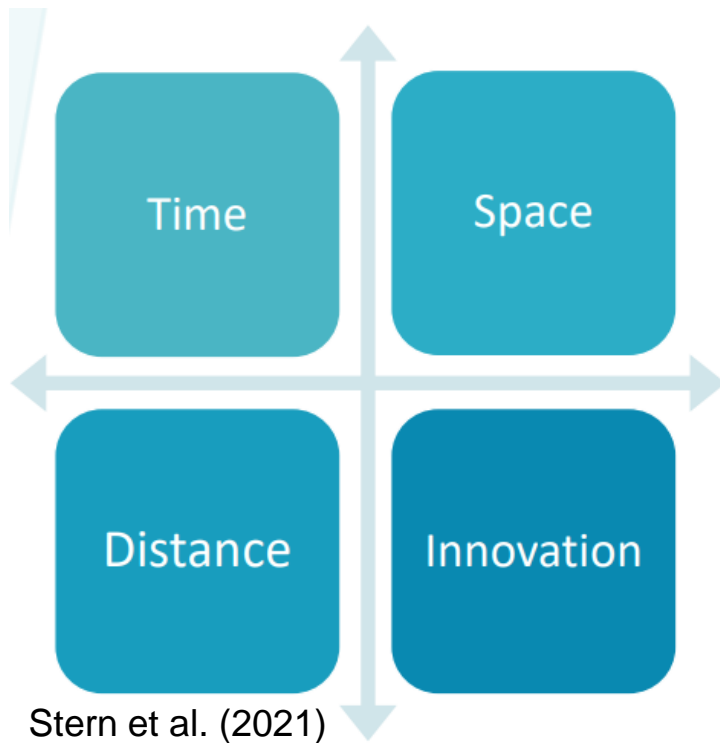
Several challenges related to social, technical, environmental and legal aspects!

Sediment is a resource and not the waste!



Practices on beneficial reuse of sediment (2/19)

4D management, challenges and constraints – *Volume Driven*



Time - Duration, regulatory timeframe, permitting window, volume of accumulation

Space – Project-limited working site access or area to accommodate sediment processing, project logistics

Distance - Sediment disposal, beneficial use sites, transportation logistics, legal aspects

Innovation - “If you always do what you’ve always done, you will always get what you’ve always gotten”

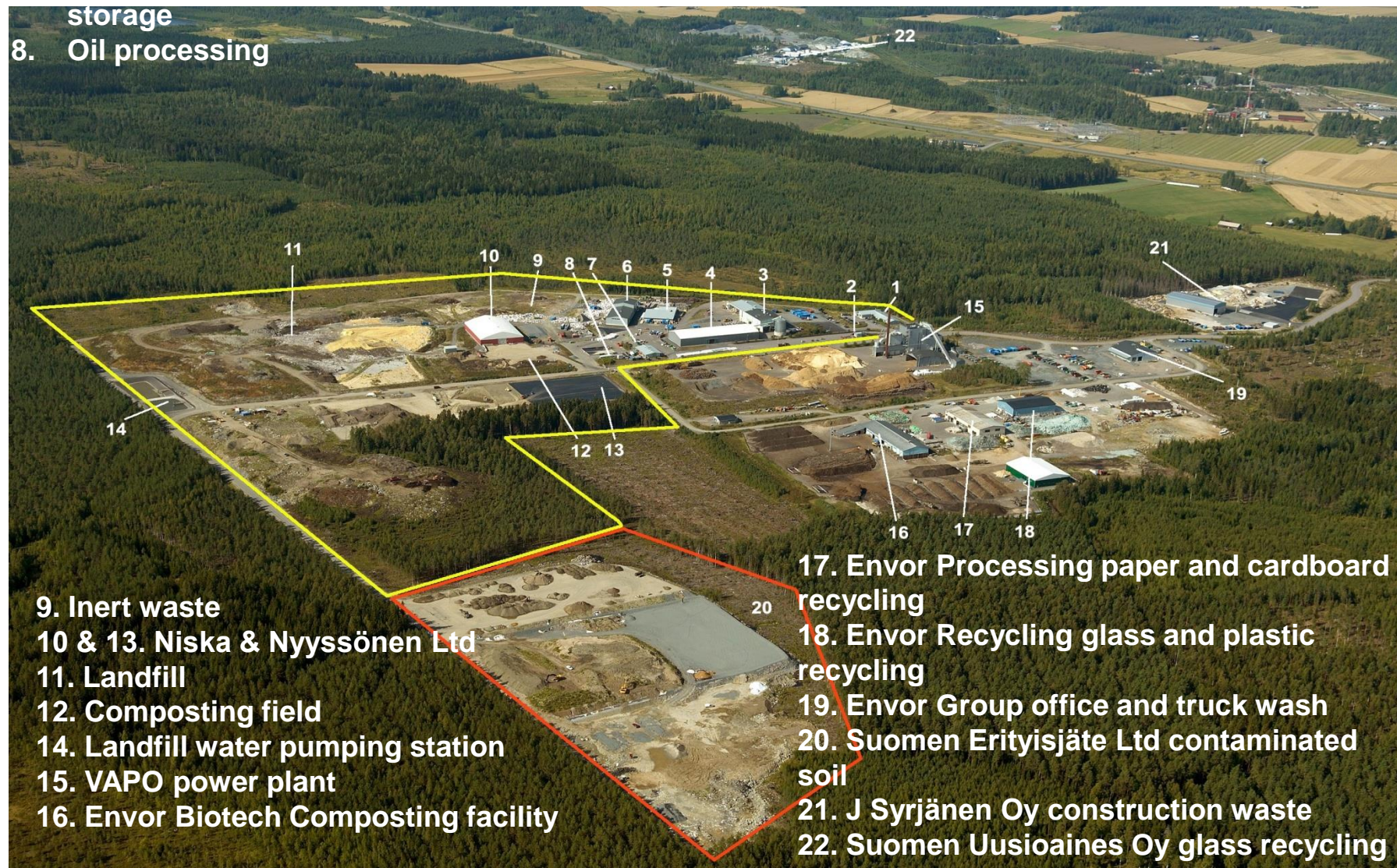
- *Hybrid Approaches*

1. LHJ office
2. Weighing station
3. REF-facility
4. REF Storage
5. CRT-Finland Ltd
6. Cool-Finland Ltd
7. Hazardous waste



-A department store for Environmental
Services
www.envitech.fi

Why not for beneficial use of sediments?



- storage
8. Oil processing

9. Inert waste
- 10 & 13. Niska & Nyysönen Ltd
11. Landfill
12. Composting field
14. Landfill water pumping station
15. VAPO power plant
16. Envor Biotech Composting facility

17. Envor Processing paper and cardboard recycling
18. Envor Recycling glass and plastic recycling
19. Envor Group office and truck wash
20. Suomen Erityisjäte Ltd contaminated soil
21. J Syrjänen Oy construction waste
22. Suomen Uusioaines Oy glass recycling

Practices on beneficial reuse of sediment (4/19)

Sediment is a resource and not a waste!

Country	Reused (% of total DM)	Remarks
Japan	90	Engineering uses (e.g. Construction of airport with DM stabilized with cement) and environmental enhancement e.g. Tidal Mudflats (DPC, 2009)
Spain	76	Used primarily for land reclamation and beach nourishment projects (Vidal, 2006)
USA	20-30	Uses include: habitat development; development of parks and recreational facilities; agricultural, forestry, and horticultural uses; strip-mine reclamation/solid waste management; shoreline construction; construction/industrial; and beach nourishment (USACE, 2007)
Netherlands	23	4% of this material is treated before reuse, 4% has a direct reuse and 15% is spread on land (Palumbo, 2007)
Ireland	20	Insignificant use of maintenance DM; 44% of capital DM reused (Sheehan et al., 2009)

Sheehan et al., 2009; Giri et al. (2019)

Land reclamation, land filling

**Manufactured topsoil enhancement and fertilizers for agricultural use, forestry
Combine with Food Waste/Compost**

**Construction materials / polymers
landscaping contouring
Engineered structural fill**

**River management (bank protection,
sandplugs, earthen dams, dikes etc.)**

Beach nourishment, shore protection

Habitat creation and restoration

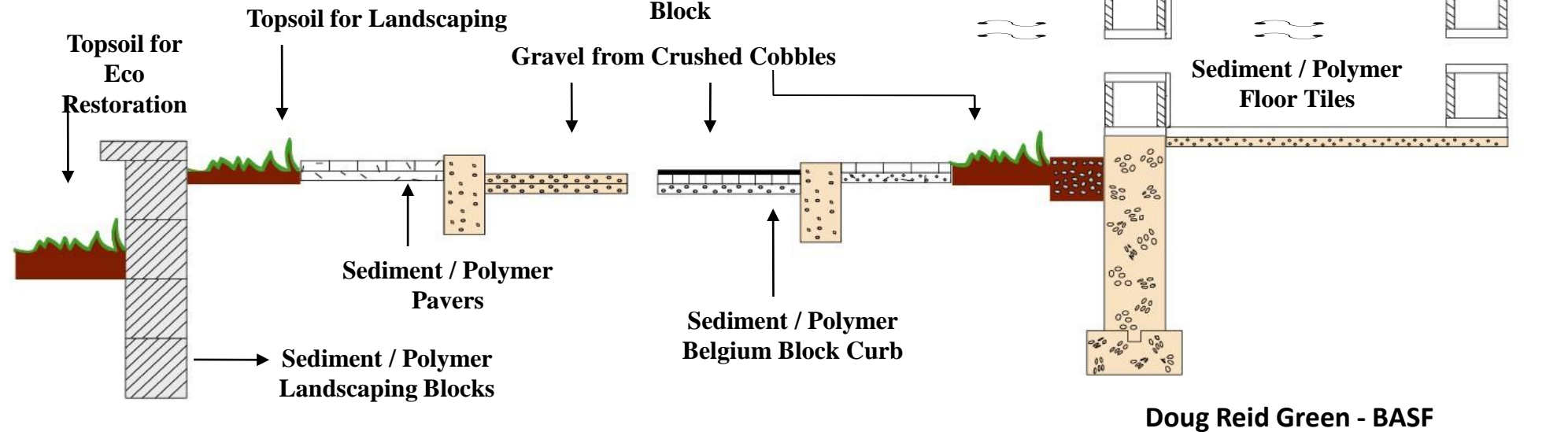
**Capping, filling for abandoned mines/
quarries**

Practices on beneficial reuse of sediment (5/19)

Sediment Based Products

**Polymer/Composite
Research
BASF Corporation
SUNY Stony Brook
Brookhaven National
Laboratory
USEPA Region 2/ORD**

(after Stern, 2005)

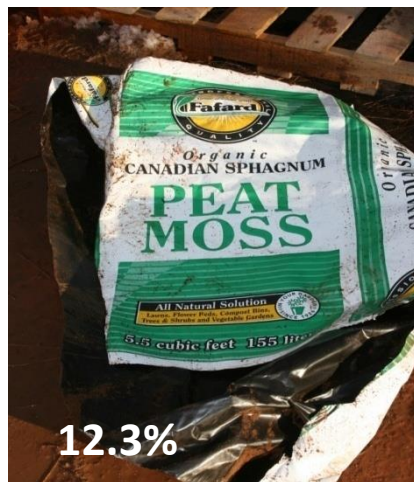


Practices on beneficial reuse of sediment (6/19)

They're making people every day, but they ain't making any more dirt — Will Rodgers

- Topsoil is being depleted avg/yr 18X faster than what is being built up in nature
 - Takes 2000 yrs to build up 2.5cm of topsoil
 - Lost to erosion, overuse of inorganic N fertilizers and farming practices
- **US/California**
 - CA agriculture depleting as much as 2.5cm TS every 25 years. 80x faster than nature
- **Developing Nations – 36x**
 - Foods grown in nutrient deficient soils / nutritional values re decreased / disease - malnutrition
- **China – 54x**
- **At this rate 48 years of topsoil left***
 - C.J. Barrow. Land Degradation, Cambridge U. Press. (1981) National Resources Inventory. Soil Conservation Service. USDA, Washington, DC (1992)
 - Nutrition Security Institute, Bellevue, Washington (2006)*

Montclair State University Manufactured Soil and
EcoMelt™ Sustainable Landscape Demonstration (2010)
Passaic River, NJ



Manufactured soil compared against residential/non-residential soil criteria

Practices on beneficial reuse of sediment (8/19)

Sediment disposal/storing facilities Compartmentalized - Renewable

Confined Disposal Facilities (CDF)
(for contaminated and non-contaminated sediments)

Open water

Upland confined placement

Near shore placement

Land reclamation



Ketelmeer is a lake in the Netherlands situated at the mouth of the IJssel river, a branch of the Rhine. For years the lake was a basin where sediments transported by the river became trapped. The waters are very shallow, less than 3 metres and the upper 30-60 cm of the fine sediment was heavily contaminated. In the 1990s the decision was made to clean up the area and to store the contaminated sediments in a newly built CDF, an artificial island named "IJsseloo", with a capacity of 20 million cubic metres. Dredged sediments that contain large quantities of sand are pumped into an adjacent sand separation lagoon. The clean, separated sand can be used for the construction of roads. The contaminated residual is then stored in IJsseloo.

Practices on beneficial reuse of sediment (9/19)



GREAT LAKES DREDGED MATERIAL CENTER FOR INNOVATION



The Toledo-Lucas County Port Authority received a \$2.5 million Ohio Healthy Lake Erie Fund grant to design and construct the Great Lakes Dredged Material Center for Innovation at the Riverside CDF in north Toledo. This project will help local leaders evaluate dredged material placement, dewatering, use of interim cover crops, soil amendments, and other testing, operations and maintenance activities necessary to plan for the full-scale implementation of the beneficial use of dredged materials for agricultural and blended soil product purposes.

Practices on beneficial reuse of sediment (10/19)

GREAT LAKES DREDGED MATERIAL CENTER FOR INNOVATION

Toledo, Ohio



LB
LAG
landscape affairs group
urban | landscape | design | research



epa.ohio.gov/dir/dredge.aspx

Practices on beneficial reuse of sediment (11/19)

GREAT LAKES DREDGED MATERIAL CENTER FOR INNOVATION

Toledo, Ohio

- **Construction:** fall 2015 to spring 2017
- **Improvements on this 14-acre project area include:**
 - Agricultural Technology Field Testing Area:** four 2.5-acre cells to demonstrate and analyze the feasibility of enhancing agricultural fields with dredged material.
 - Edge-of-Field Filter System Research Area:** this water management and treatment system can support future nutrient runoff reduction research.
 - Blended Soil Production Area:** dredged materials will be blended with other materials, including leaf compost from the city of Toledo's composting facility.
 - Mooring Area:** improvements will be made at the riverfront for a dredged material offloading area.
 - Site Access and Infrastructure:** potential improvements include a railroad crossing upgrade, road upgrade/extension, water and sewer extensions, and security fencing and gates.
- This project will help local leaders evaluate dredged material placement, dewatering, use of interim cover crops, soil amendments, and other testing, operations and maintenance activities necessary to plan for the full-scale implementation of the beneficial use of dredged materials for agricultural and blended soil product purposes.



Practices on beneficial reuse of sediment (12/19)

Development of artificial islands (Japan)

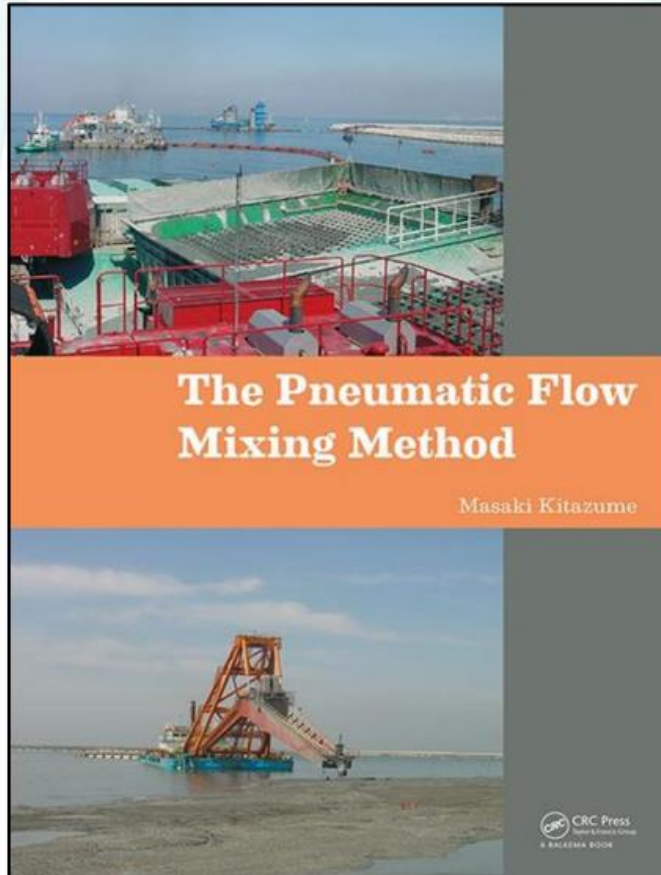
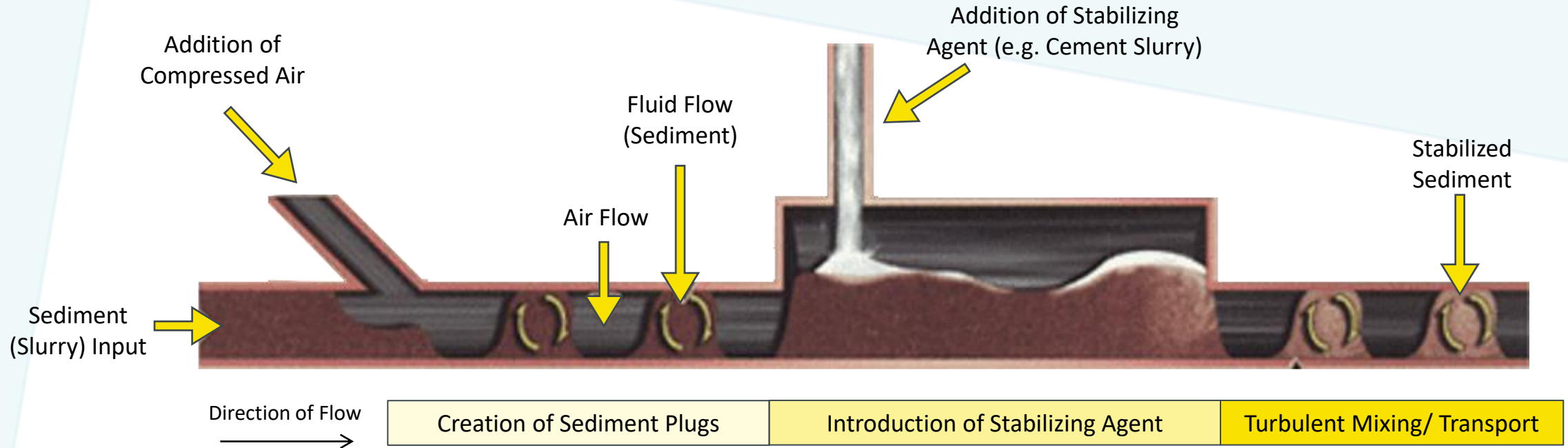


Figure 4-59. Some examples of artificial islands in Japan (upper pictures) and the workflow and features of dredged material recycling system (www.umesbunkyo.or.jp/english/english.pdf)



Practices on beneficial reuse of sediment (13/19)

Pneumatic Flow Tube Mechanism



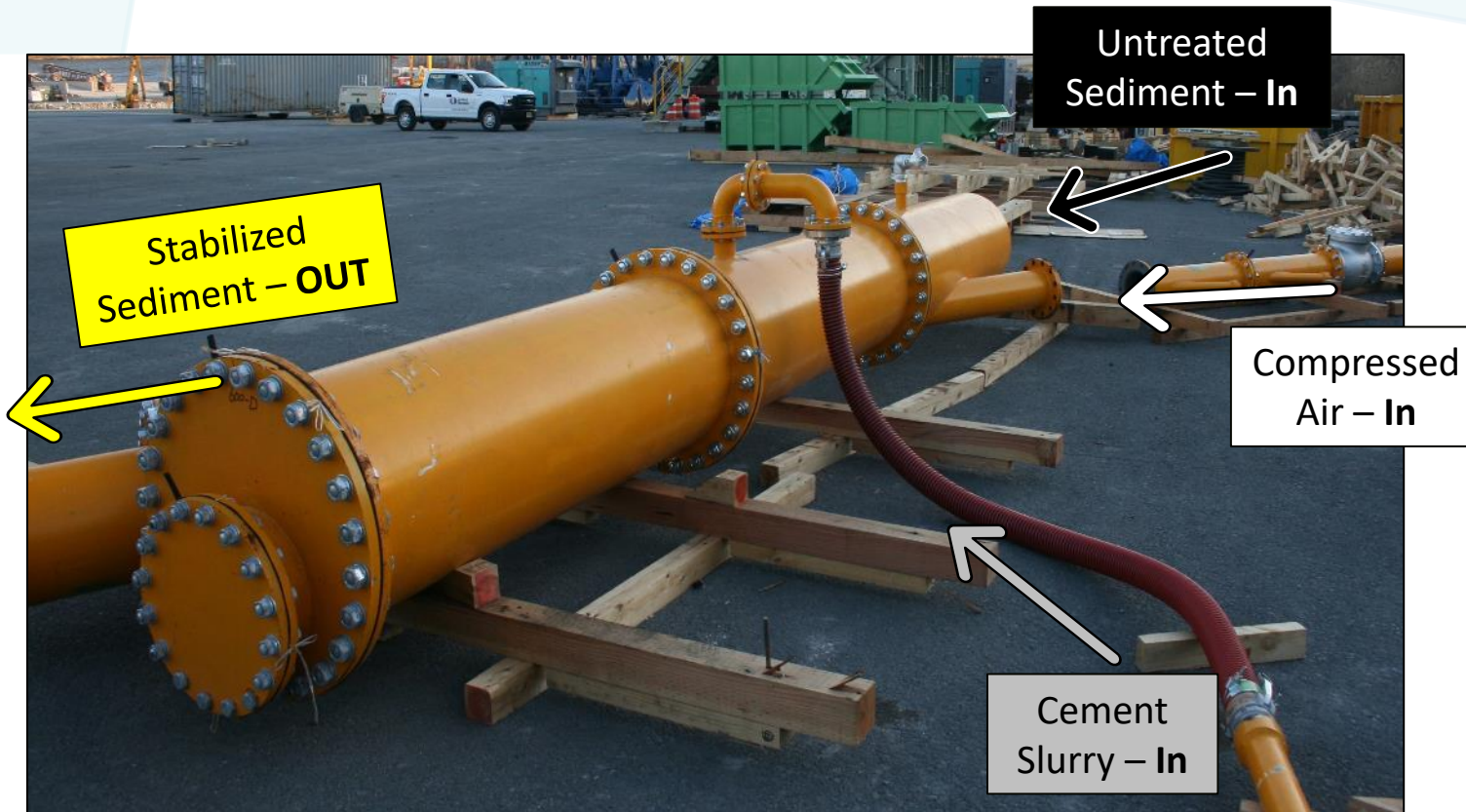
Soft sediment is broken into “plugs” by compressed air. Plugs reduce pipe surface friction, easing flow. **During transport, cement and sediments are mixed by the turbulent flow within the “plug”.**

(Kitazume 2002)

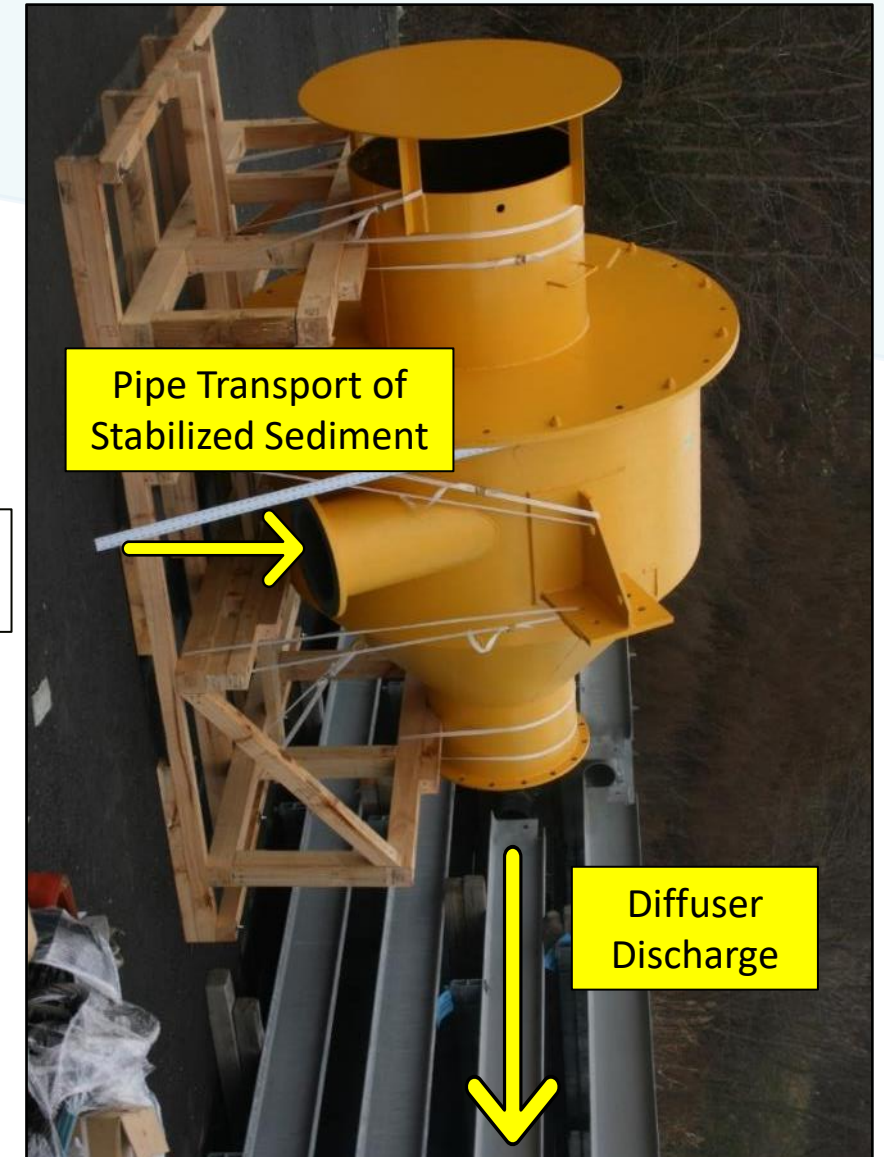


Practices on beneficial reuse of sediment (14/19)

PFTM: Process Equipment



PFTM2000 Mixing Tool - 2,000 CY/day (8-hr shift)

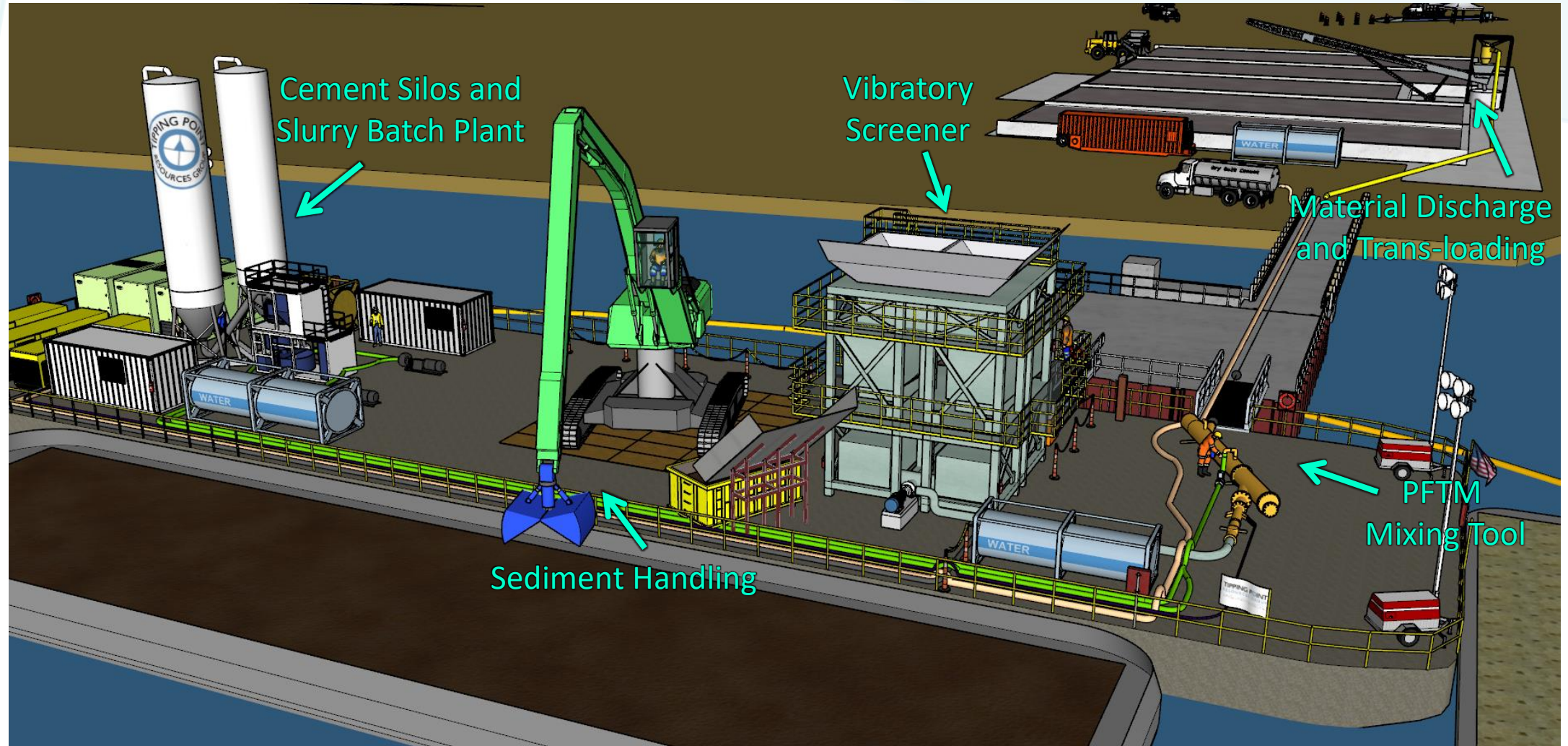


PFTM Cyclone Discharge Diffuser



Practices on beneficial reuse of sediment (15/19)

Barge-mounted PFTM Operations Mobile Operating Sediment Engineering System (MOSES)





Practices on beneficial reuse of sediment (16/19)

PFTM: Processed Sediment 0 to 72 hours after placement



Dredged Sediment Prior to Stabilization



*Freshly-placed PFTM Processed Sediment (8%
Portland cement)*



7.5% Portland cement
Immediately after mixing



7.5% Portland cement
After 24 hours



5% Portland cement
After 72 hours



Practices on beneficial reuse of sediment (17/19)

Stabilized Sediment Beneficial Use Applications



Environmental

Brownfield
Redevelopment

Coastal
Restoration

**Haz Waste Remediation
(Superfund)**

Landfill Cover

Mine Tailings
Management

Coal Ash
Residuals



Structural

Waterfront Bulkhead &
Trench Fill

**Berm & Road
Construction**

Land Reclamation

Structural
Capping

**Coastal Resilience
(Elevation)**

Port Expansion



Practices on beneficial reuse of sediment (18/19)

TEC

Road construction				
Road embankment, fines	Road embankment, sand	Road embankment, self clear	Road sub base	Parking lot road surface
				

Soils				
Soil elevation (meadow depo)	Lift up of Lowlands	Wet storage (deposit)	Filter cake press	
				

Soils				
Nature development, on land	Nature development, wetland	Sand separation	Hydrocyclone for sand separation	Natural Ripening
				

Soils				
Enhanced ripening with geotextiles	Landfarming	Energy crops	Sound walls	Capping of deposits
				

Practices on beneficial reuse of sediment (19/19)

Dikes and safety against flooding

Trench shoring



River Embankment



Dike, river site scouring protection



Dike, land site terrace

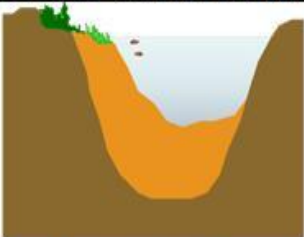


Lake, erosion protection

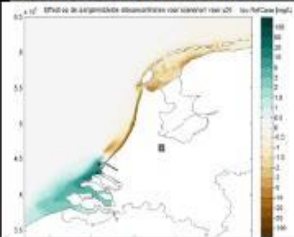


Dikes and safety against flooding

Shallow lakes, ecological enhancement



Reallocation at sea



Sediment store (baggerbuffer)



Sediment settler (trapping)



Terp (local ground elevation)



Building industry

Brick production



Artificial gravel production



Artificial basalt



Concrete for roads/coastal defence



Cement mortar production



Building industry

Cement granulate production



Stabilisation/Solidification



Management of sediment-induced problems at THC: First screening of possible measures and challenges

Characterization of the sediment-induced problems at THC

Significant sedimentation along the Channel reservoir, particularly within 50 km upstream of the dam leading to significant storage loss (about 63% of total storage)

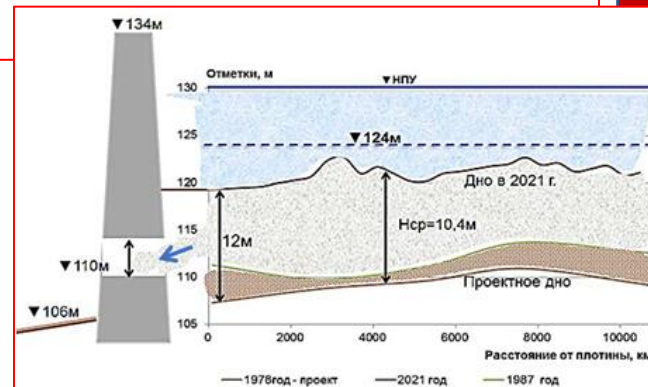
Possible sedimentation problem in other reservoirs, i.e. Kaparas, Sultansandjar and Koshbulak (no quantitative information!)



Affecting agricultural and drinking water supply

Significant sedimentation in front of the dam leading to poor functioning of hydropower

Affecting energy production



Management of sediment-induced problems at THC (1/28)

Screening sediment handling measures

Structural

Sediment bypass
channel/tunnel

Renovation/adaptation
of undersluices

Off-channel reservoir(s)

Dam heightening

Replacement project

Non-structural

Storage relocation

Operation optimization

Water conservation/
water loss reduction

Improving/adapting
irrigation practices
and methods

Monitoring and
forecasting system

Recurrent

Replenishment

Sluicing and flushing

Dry excavation

Dredging (hydraulic, hydrosuction,
air lift, mechanical-lift (bucket,
clamshell, dragline, backhoe),
agitation dredge)

Combination of measures

Management of sediment-induced problems at THC (2/28)

Sediment removal options

Dredging

Hydraulic

Hydro-suction

Air-lift

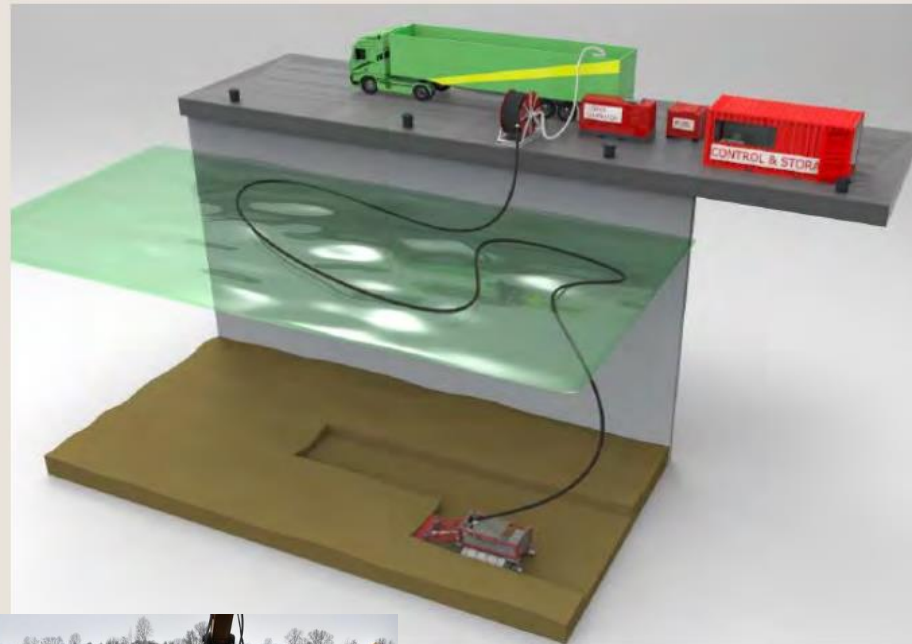
Mechanical-lift
(bucket, clamshell,
dragline, backhoe)

Agitation dredge

Diver-assisted
dredging near the dam

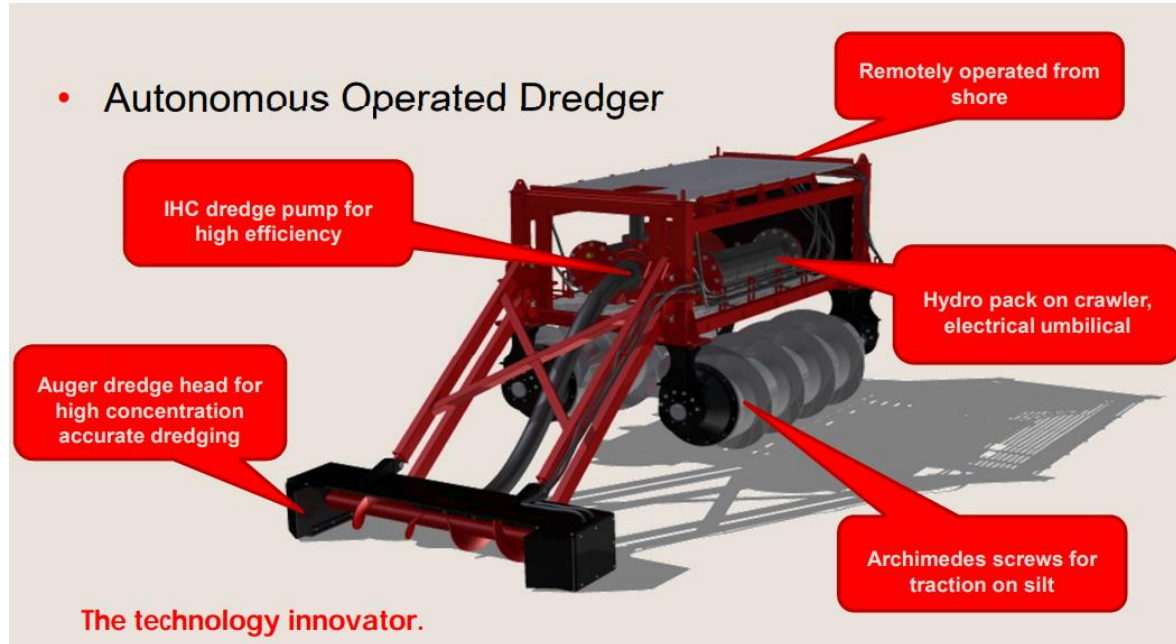


Reservoir dredging



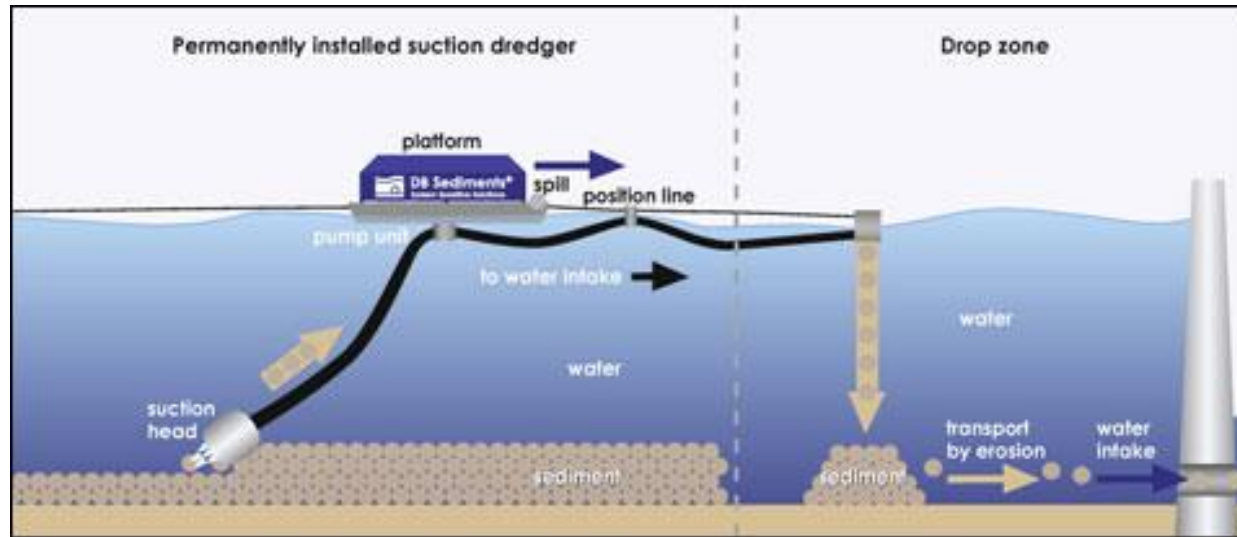
Management of sediment-induced problems at THC (3/28)

Sediment removal options



Management of sediment-induced problems at THC (4/28)

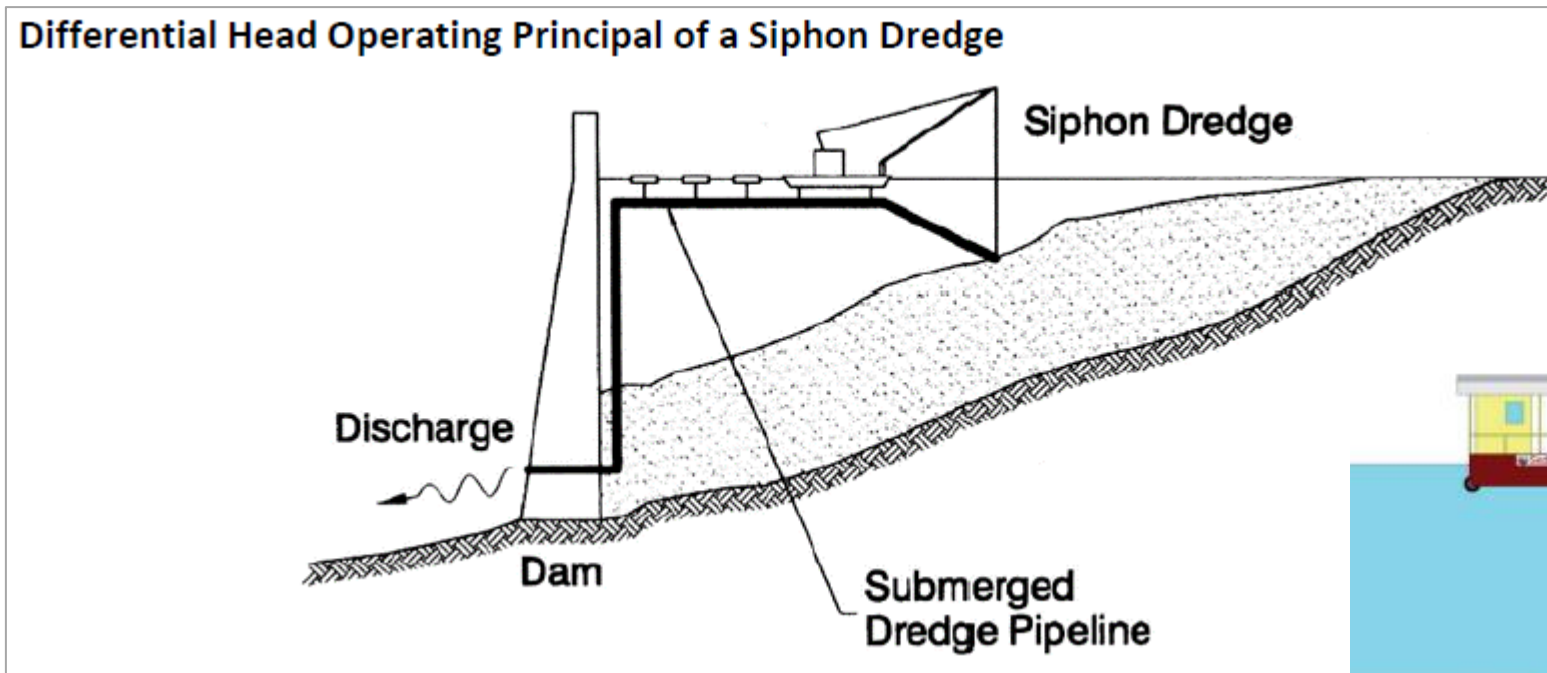
Sediment removal options



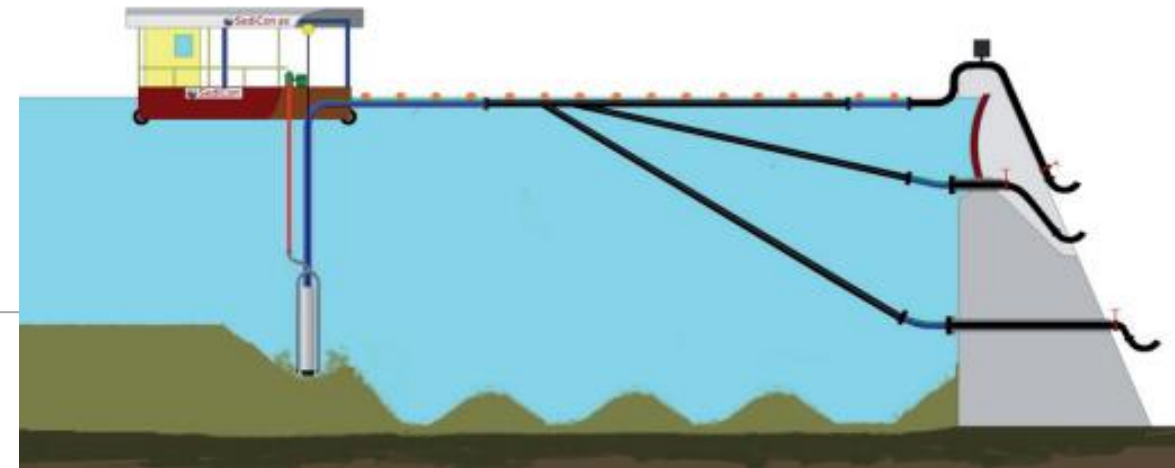
Management of sediment-induced problems at THC (5/28)

Sediment removal options

Hydrosuction (syphon) dredging



Moris and Fan (1998)

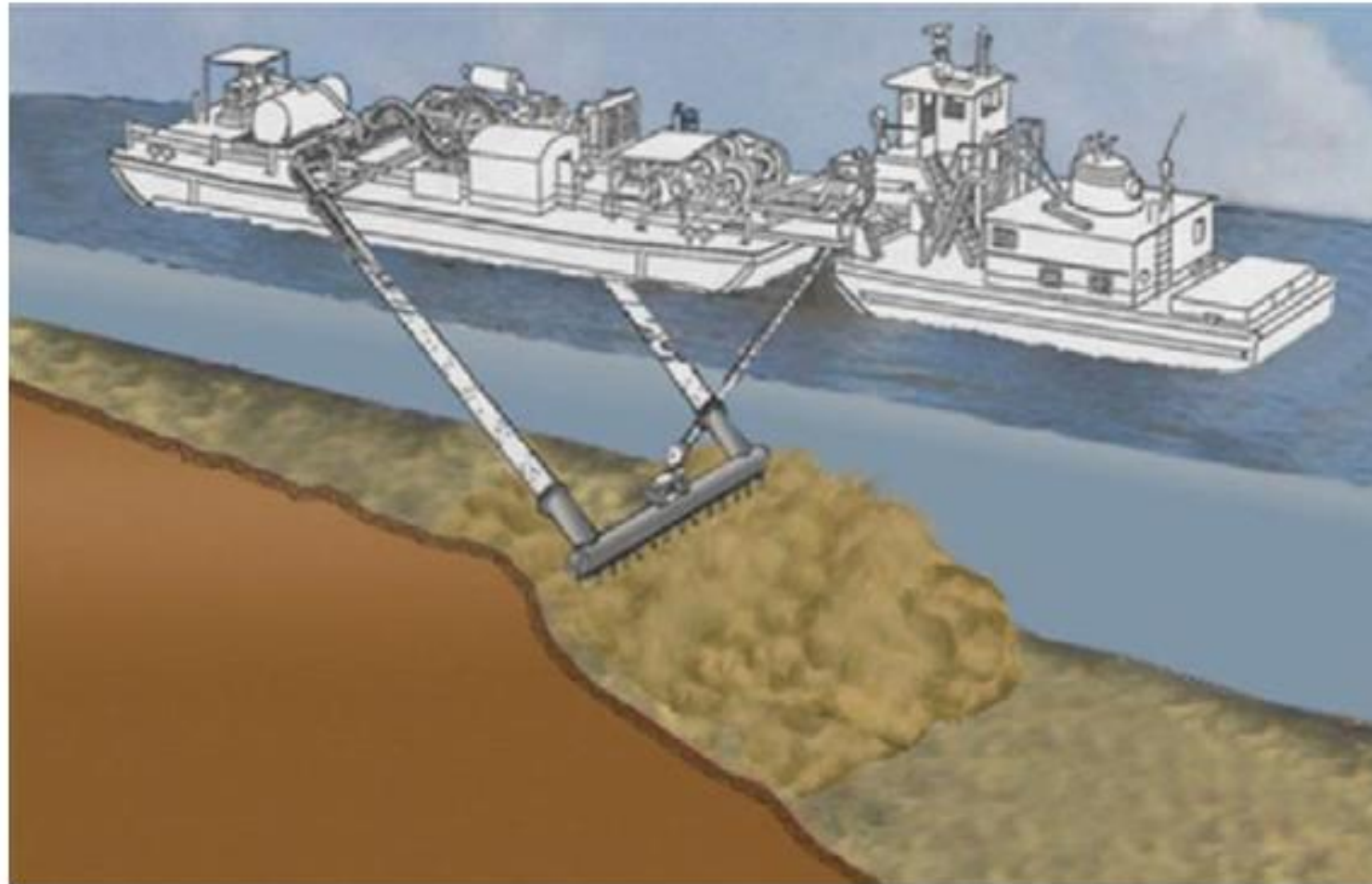


Courtesy: Sedicon

Management of sediment-induced problems at THC (6/28)

Sediment removal options

Water Injection Dredge (WID) – Generating density current and transporting



Management of sediment-induced problems at THC (7/28)

Sediment removal options

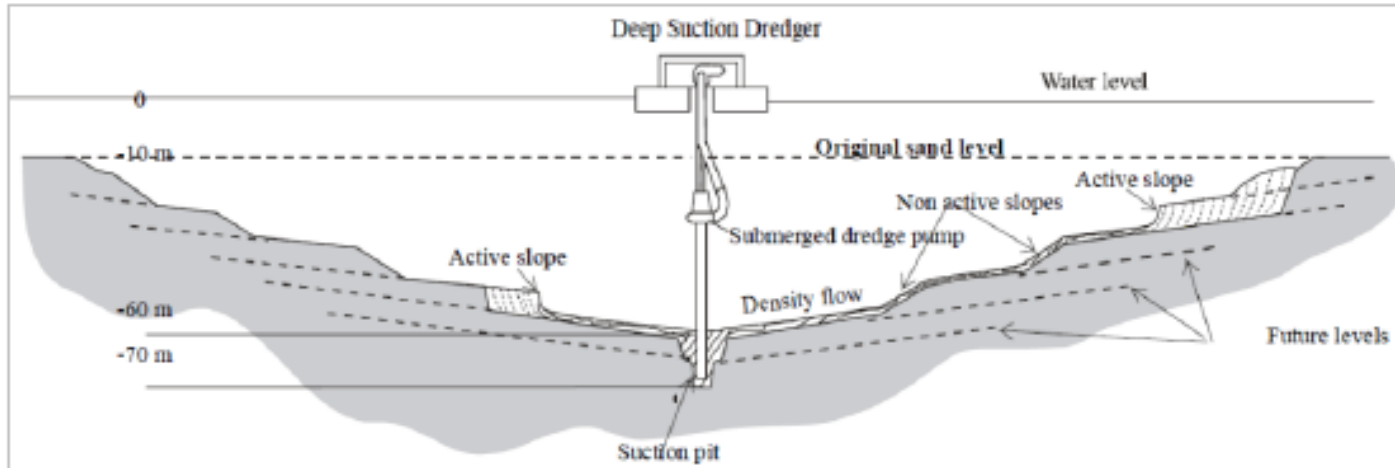


Figure 4-34. The breaching process during suction dredging (*van Rhee, 2003*)

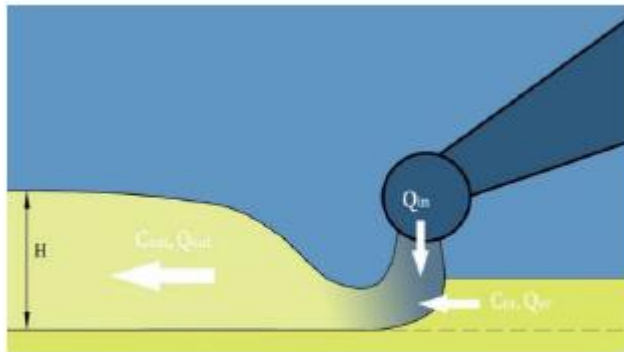


Figure 4-37. Density current created by water injection dredging (*Bronsvort, 2013*)

Giri et al. (2019)



Figure 4-35. A continuous sediment transfer technology (*DB Sediment*)



Figure 4-36. A EPDS installation in a Japanese reservoir (*Temmyu et al., 2013*)

Management of sediment-induced problems at THC (8/28)

Sediment removal options

Многоцелевой Земснаряд **Амфибия - Ватермастер**

Classic V (2017г.) – мощность 900м3/час

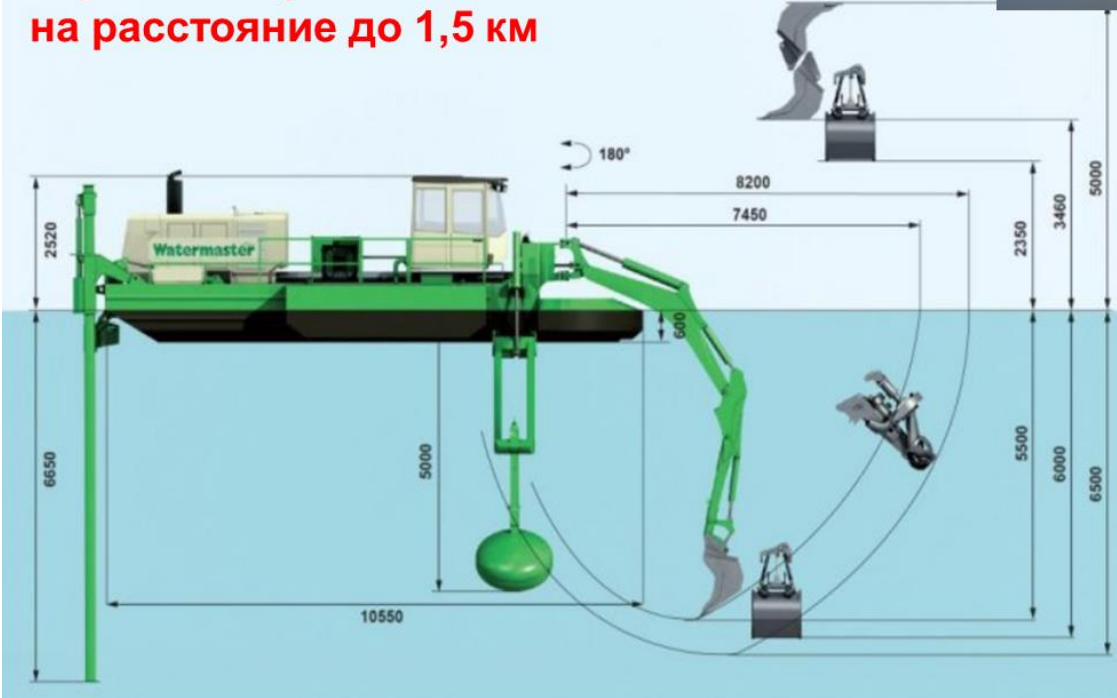
Classic IV - 600 м3/ч

Возможность работы **до глубины 6,5 м**

длина стрелы 16,00 м

перекачка пульпы

на расстояние до 1,5 км



Courtesy: M. Ikramova

Management of sediment-induced problems at THC (9/28)

Transportation and disposal options

Transportation

Trucking/shipping

Slurry pipe

Conveyor

Pneumatic transfer

Disposal

Disposal Facilities

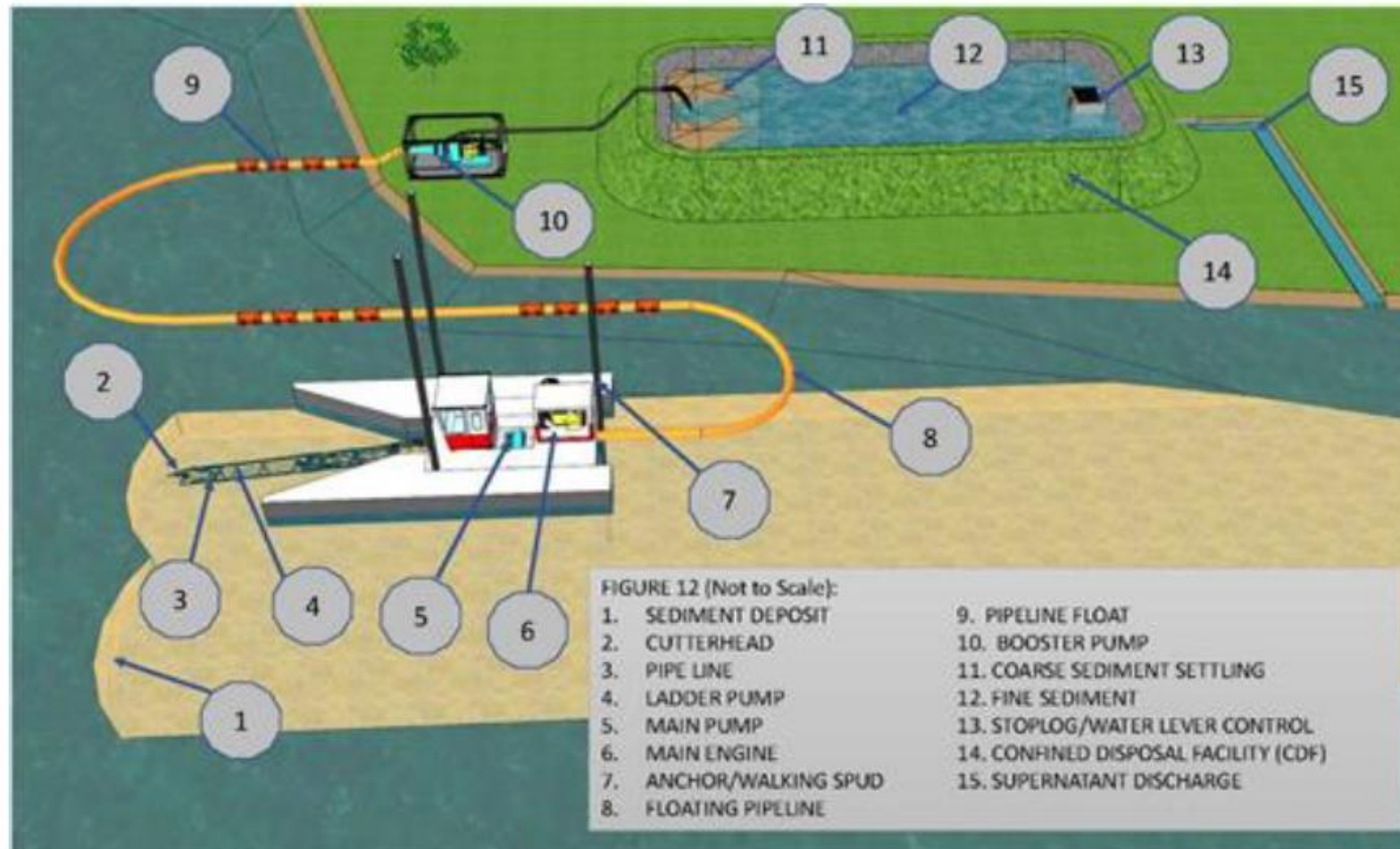
Beneficial reuse



Management of sediment-induced problems at THC (10/28)

Transportation and disposal options

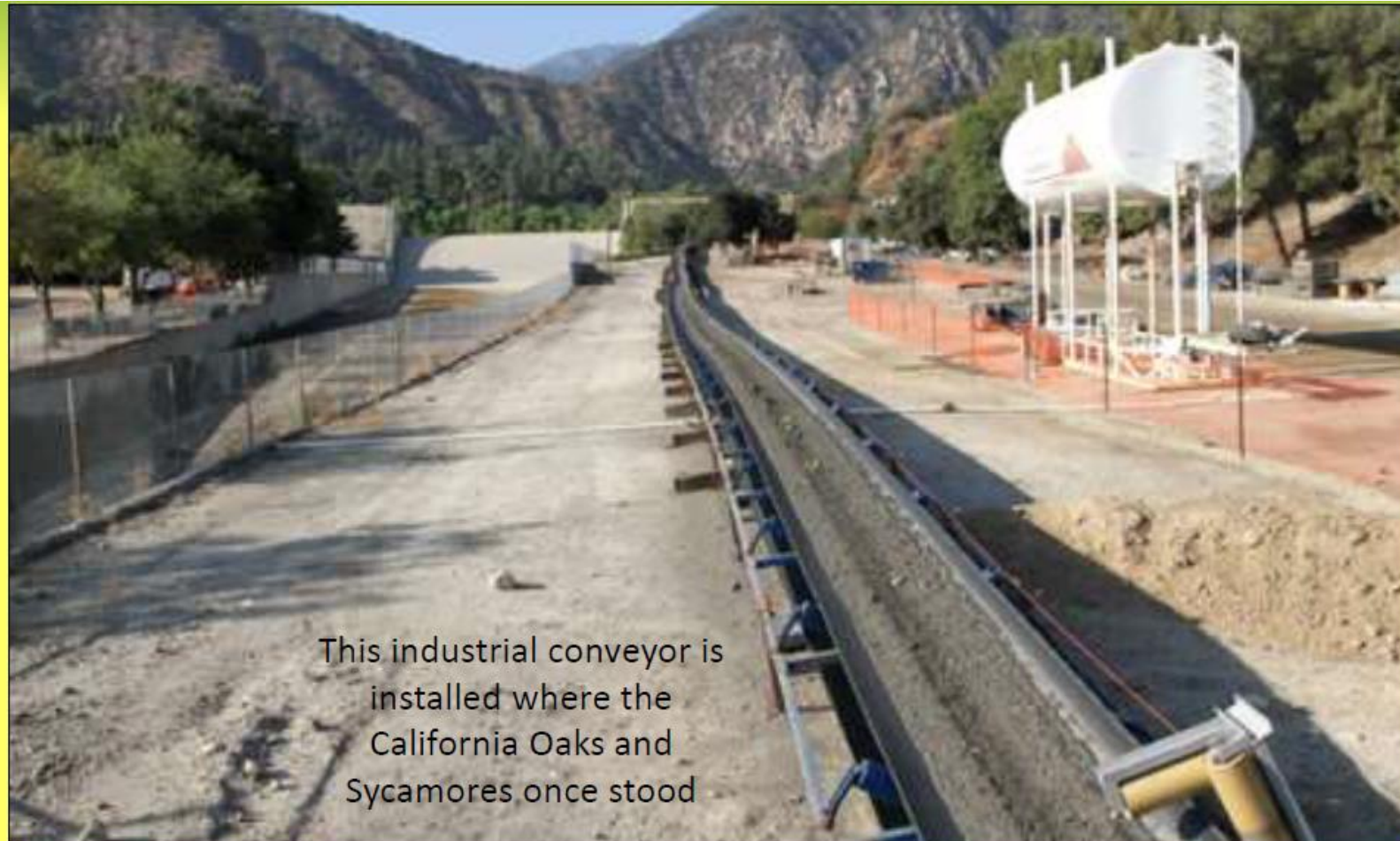
System Components of a Swinging Ladder Cutterhead Suction Dredge Depositing Slurry in a Confined Disposal Facility



Source: J. F. Brennan

Management of sediment-induced problems at THC (11/28)

Transportation and disposal options



This industrial conveyor is installed where the California Oaks and Sycamores once stood

Management of sediment-induced problems at THC (12/28)

A first quick glance and propositions

- ❑ **Sediment removal with beneficial reuse options (with a possibility of establishment of production unit/industries in the area)**
 - ✓ Topsoil enhancement for agricultural use, fertilizer, afforestation
 - ✓ Construction materials/products
 - ✓ River management (bank protection, sandplugs, earthen dams, dikes etc.), river ecology, habitat creation and restoration
 - ✓ Downstream continuity and bypass (replenishment, sediment bypass tunnel/canal/new flushing channel etc.)



Management of sediment-induced problems at THC (13/28)

A first quick glance and propositions

- ❑ **Additional reservoir(s) to increase storage capacity**
 - ✓ Rehabilitation and extension of existing secondary reservoirs at THC
 - ✓ Construction of additional reservoir(s)
- ❑ **An integrated approach** considering **optimal use of water**, **efficient agricultural practices**, **minimizing water loss** (e.g. in irrigation canals) as well as **catchment/river/land-use management** in complement with establishment of proper **water+sediment information**, **forecasting and reservoir operation systems**, **rules and regulation**

Social, technical, environmental and economic feasibility of proposed measure(s)

Management of sediment-induced problems at THC (14/28)

Rehabilitation and improvement of agricultural lands

Existing issues

- ✓ Loss of agricultural lands due to water scarcity
- ✓ Salinization of topsoil that requires regular washing before cultivation

Use of removed sediment for the improvement of agriculture

- ✓ Enhancement/rehabilitation of topsoil ([maybe regularly as an alternative to washing the topsoil as being practiced presently](#))
- ✓ Use of suitable materials as fertilizer
- ✓ There is also work that has been conducted utilizing the introduction of food waste with sediments to create a topsoil. At least in the US, 90% of food waste goes to landfills.
- ✓ A liquid solid separation sediment washing process could also be employed that provides a dewatered filter cake in the end step. Material would need a front-end screener before going into the system to pull out debris (detritus).



Management of sediment-induced problems at THC (15/28)

Manufacture of building materials

- ✓ Road construction, bank protection, riprap, construction blocks/bricks etc.
- ✓ Geotechnical applications that involve sediment stabilization with CKD (Cement Klin Dust), furnace slag (if available) and Portland cement. The uses are focused on roads, paths, engineered fill and many of the applications.



Management of sediment-induced problems at THC (16/28)

Reuse for river management and improvement measures

- ✓ Sediment management measures at Ruslovoe reservoir (e.g. dikes for sediment trapping)
- ✓ Embankments and sandplugs if required



Management of sediment-induced problems at THC (17/28)

Sediment disposal/storage/treatment

- ✓ There appear to be enough space for creating confined and upland disposal and treatment (e.g. ripening) facilities that could be outside or even within reservoir extent.
- ✓ Who are the landowners and what are logistic and legal constraints?
- ✓ Sustainability of sediment disposal and treatment facilities

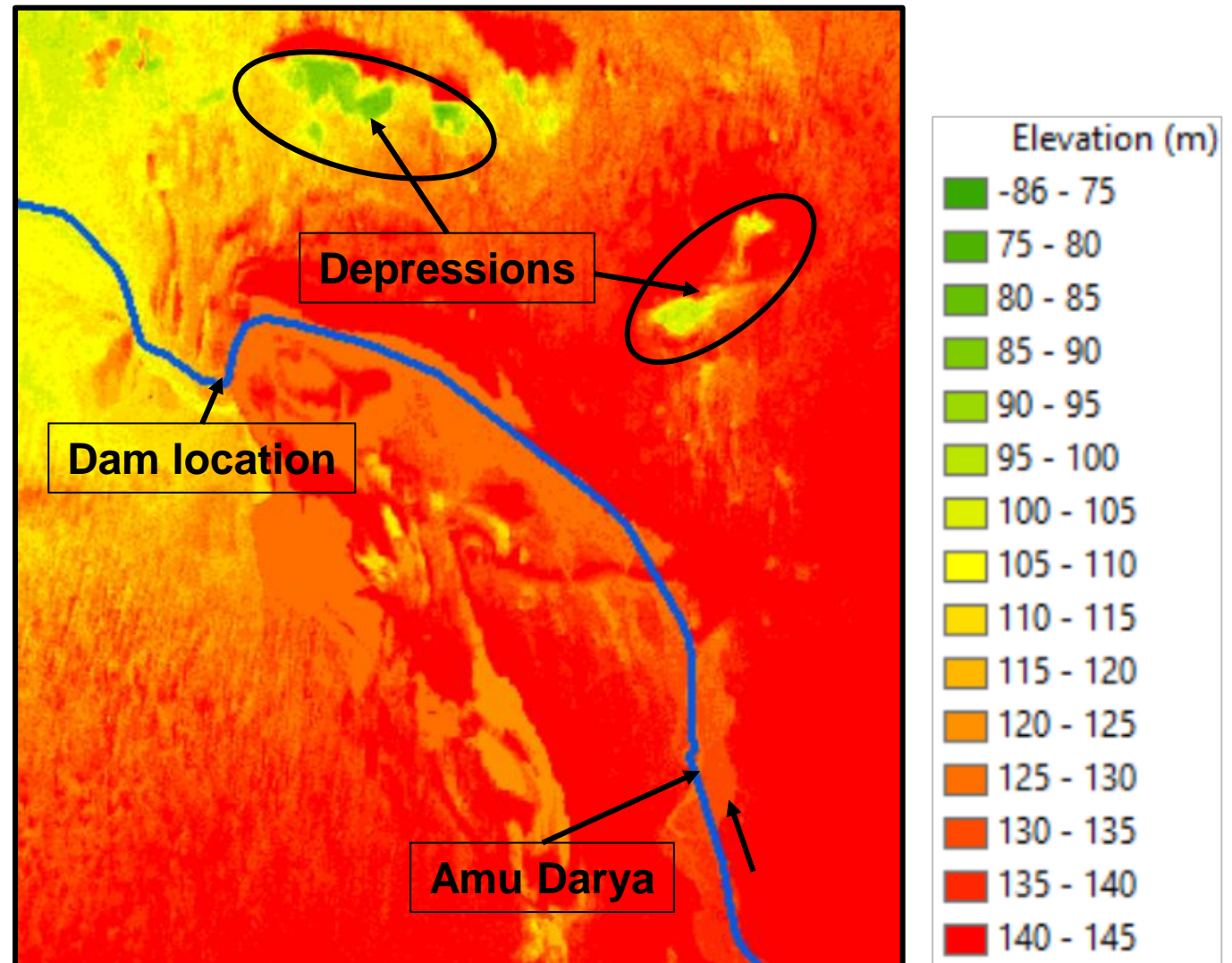


Management of sediment-induced problems at THC (18/28)

Increasing water storage outside of the Channel reservoir

Construction, enhancement of
additional reservoirs

Digital Elevation Model (DEM)
SRTM 30 m



Management of sediment-induced problems at THC (19/28)

Increasing water storage outside of the Channel reservoir

Construction, enhancement of additional reservoirs

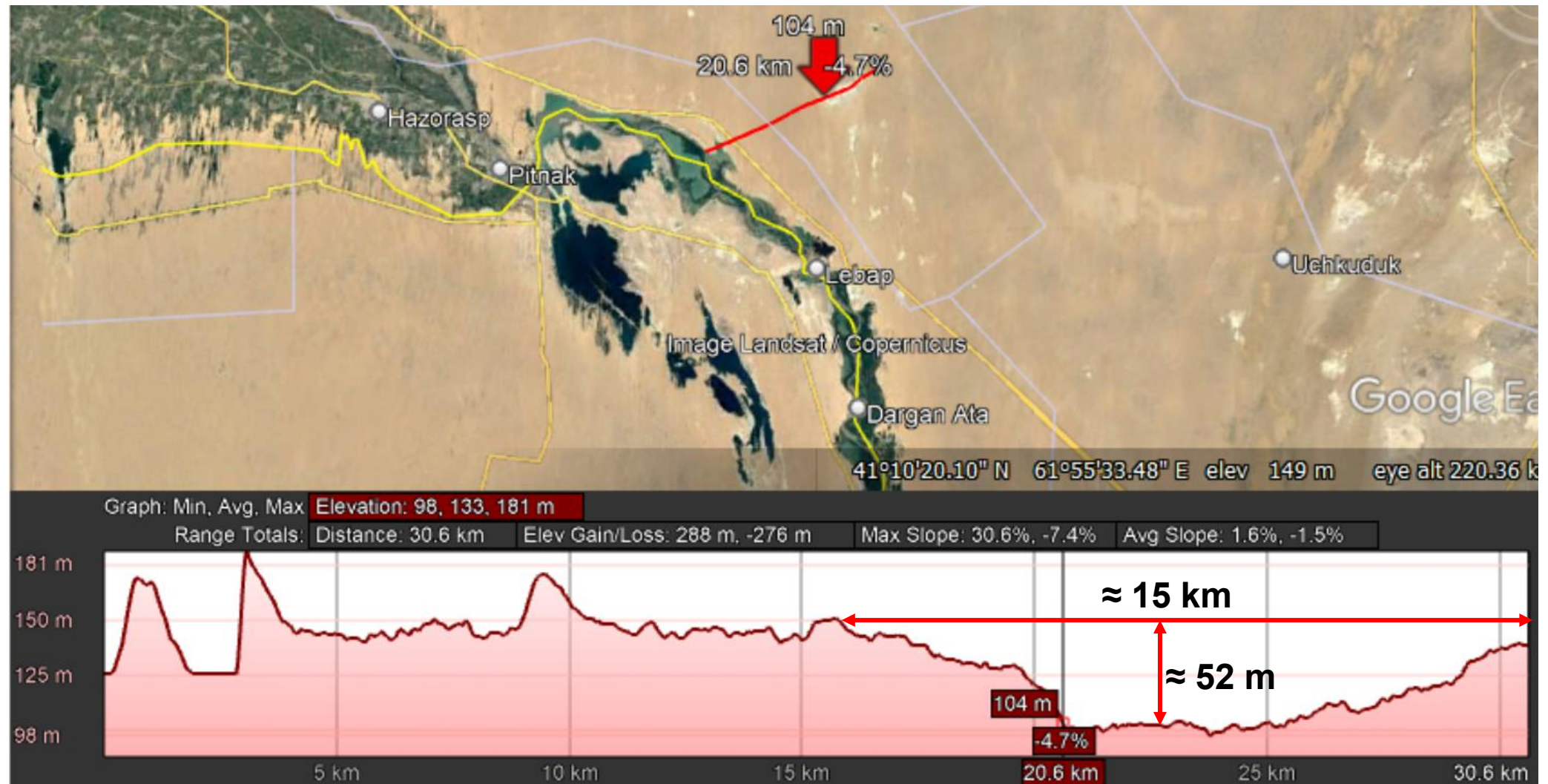
- ✓ Possibility of the construction of additional reservoirs near the Ruslovoe reservoirs (in both Uzbekistan and Turkmenistan sides) shall be considered for feasibility study given that there are some depressions suitable for the purpose (within the range of 25-30 km).
- ✓ There was already an effort (and even partly built infrastructures as we understood!) to construct the additional reservoir at Uzbekistan side.

Rehabilitation and enhancement of Kaparas, Sultansanjar and Kushbulak reservoirs!



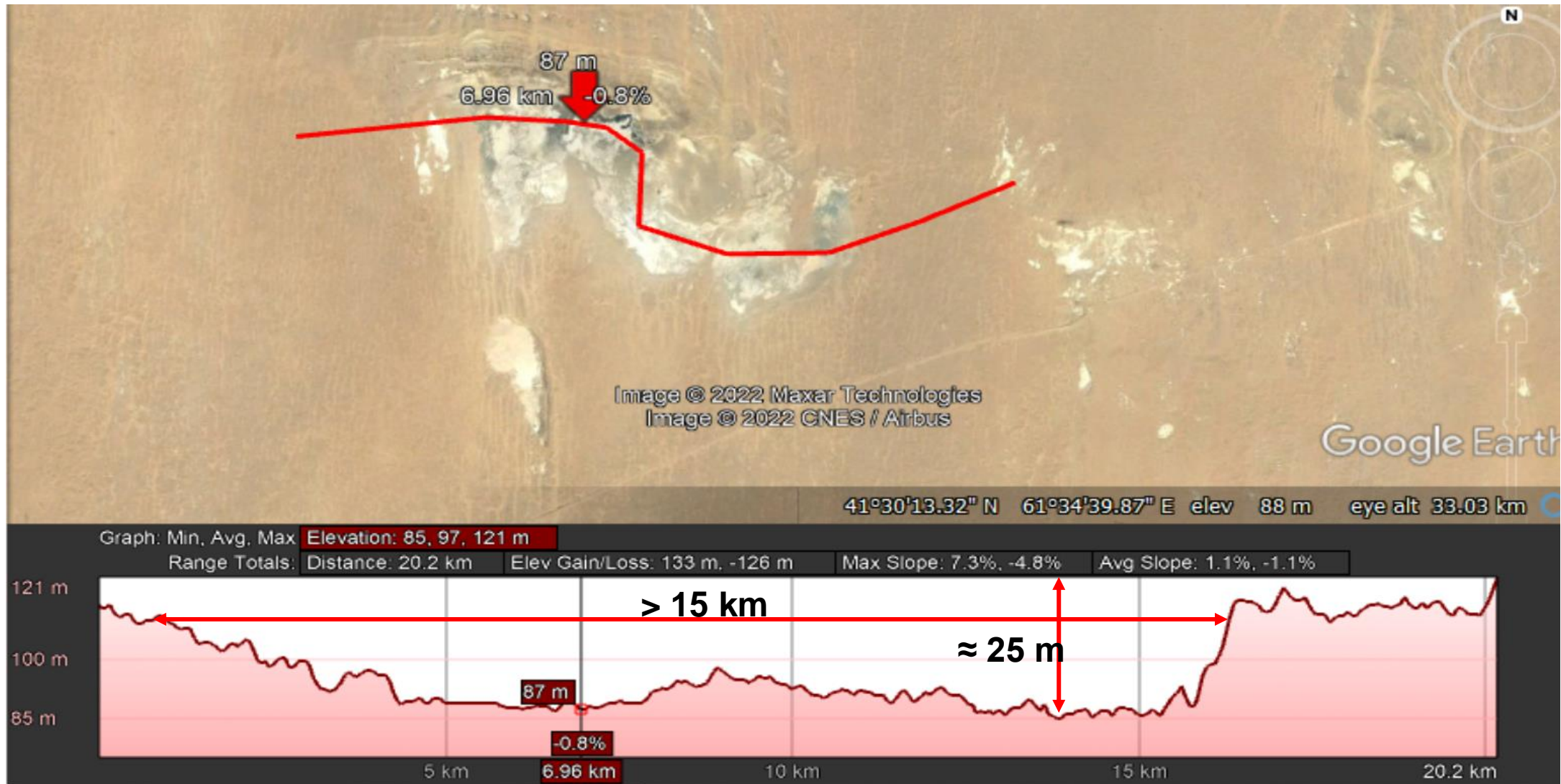
Management of sediment-induced problems at THC (20/28)

Construction, enhancement of additional reservoirs



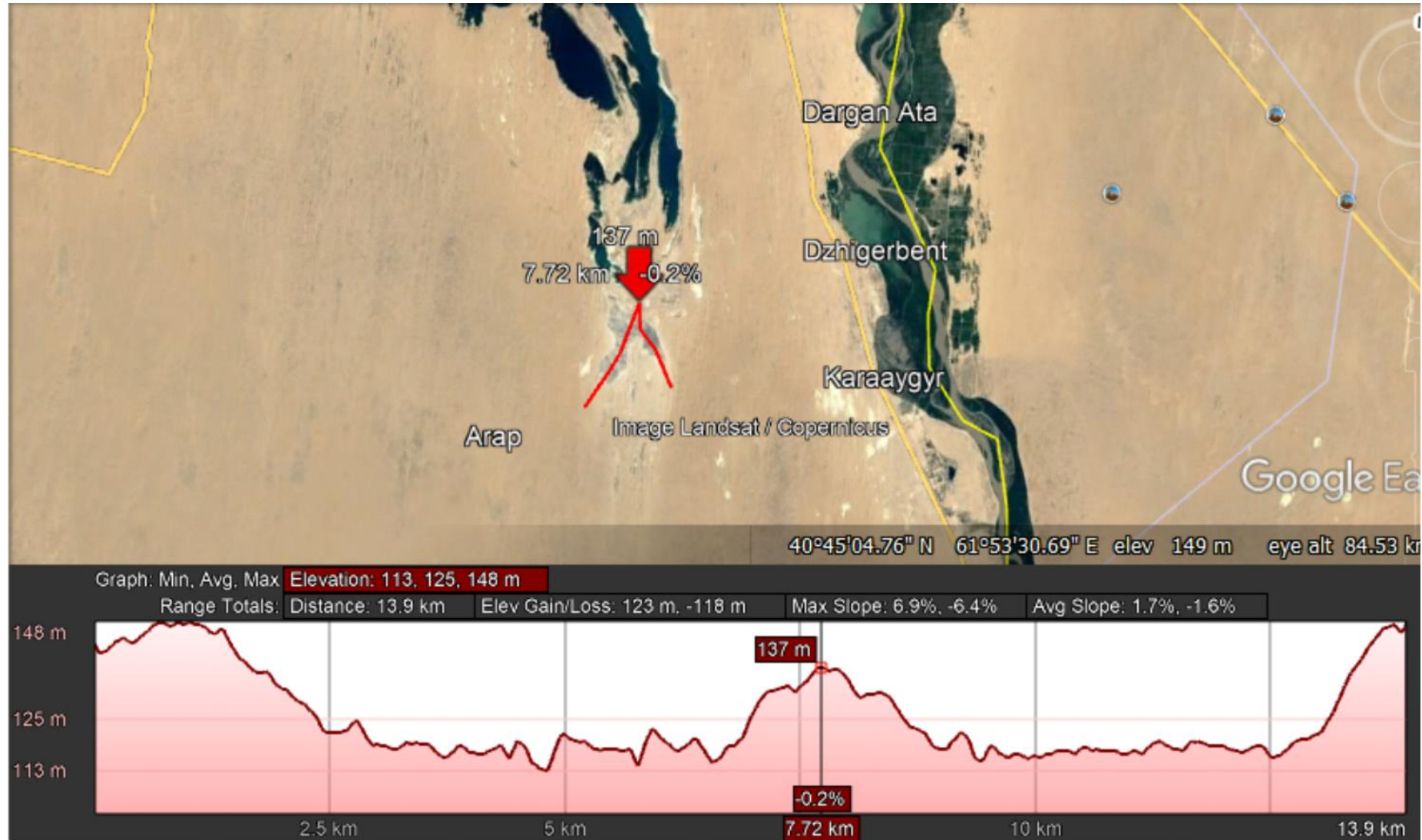
Management of sediment-induced problems at THC (21/28)

Construction, enhancement of additional reservoirs



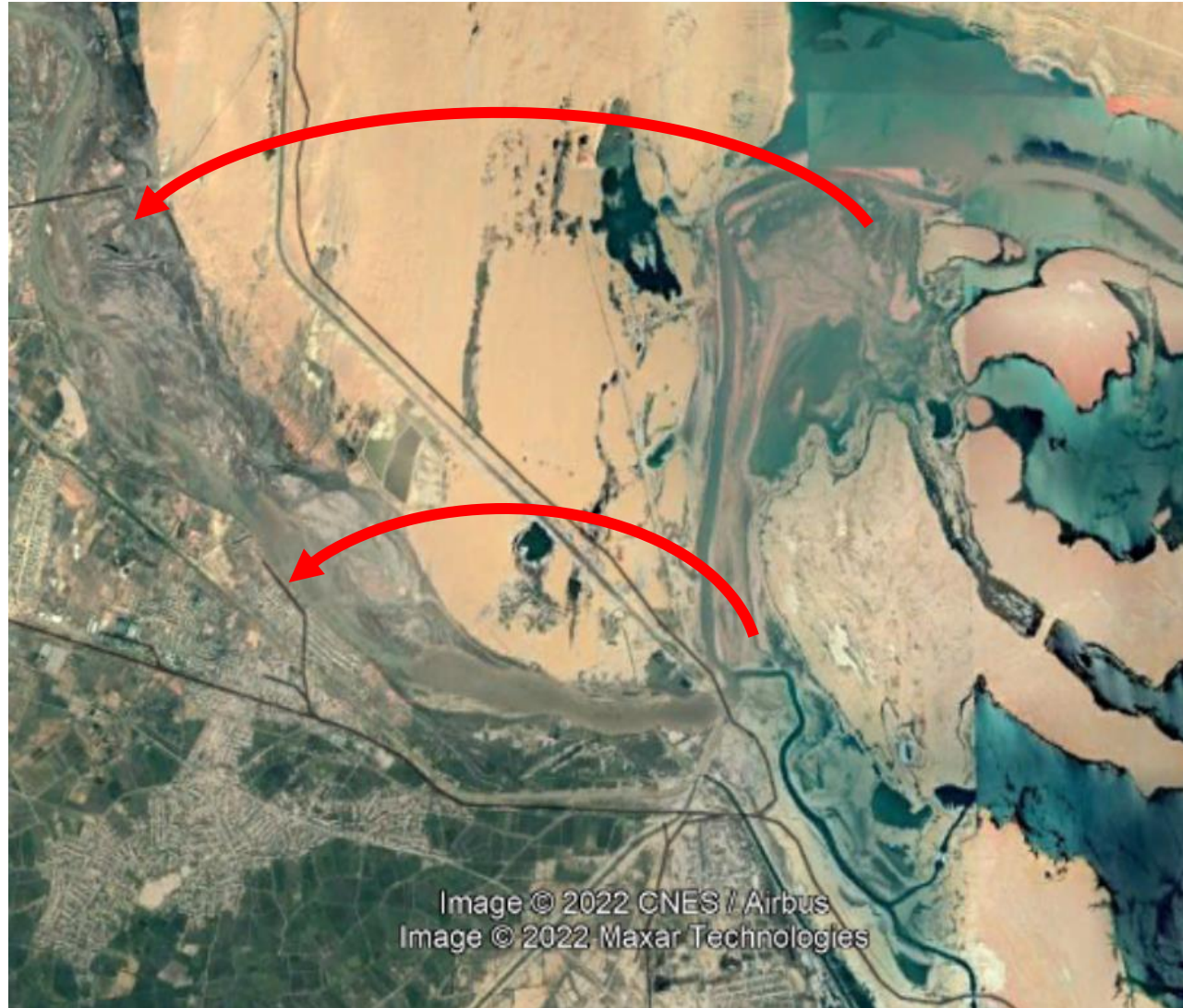
Management of sediment-induced problems at THC (22/28)

Construction, enhancement of additional reservoirs



Management of sediment-induced problems at THC (23/28)

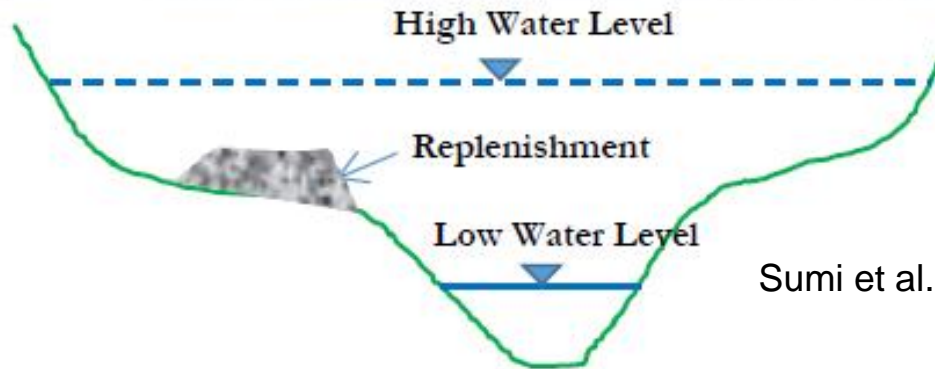
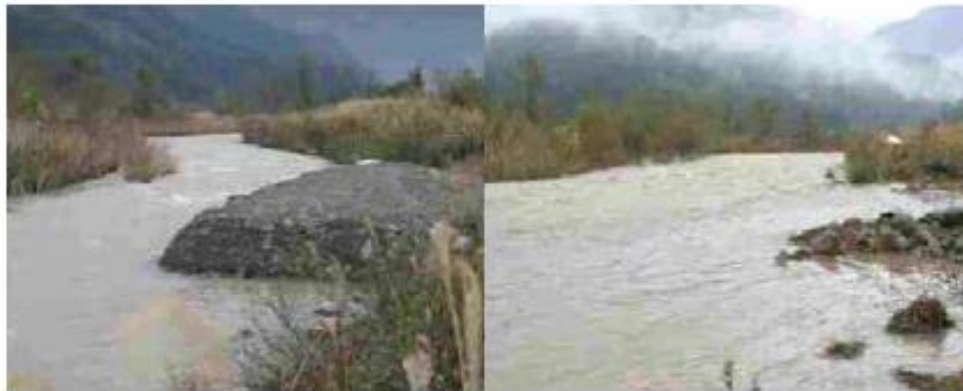
Sediment bypass channel/tunnel



Management of sediment-induced problems at THC (24/28)

Downstream replenishment

- ✓ For maintaining downstream sediment balance
- ✓ Relatively small amount of sediment



Sumi et al. (2010)



Sediment replenishment in Isar River, Germany (Courtesy: S. Hartman)

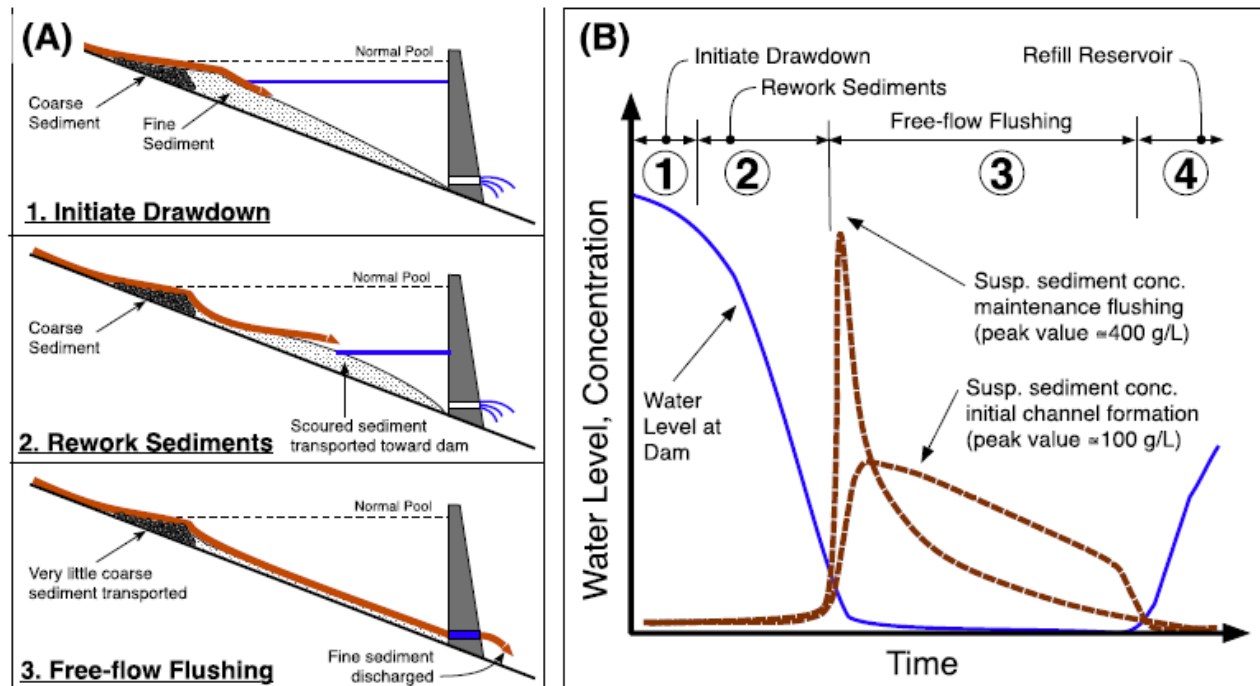
Management of sediment-induced problems at THC (25/28)

Sluicing and flushing

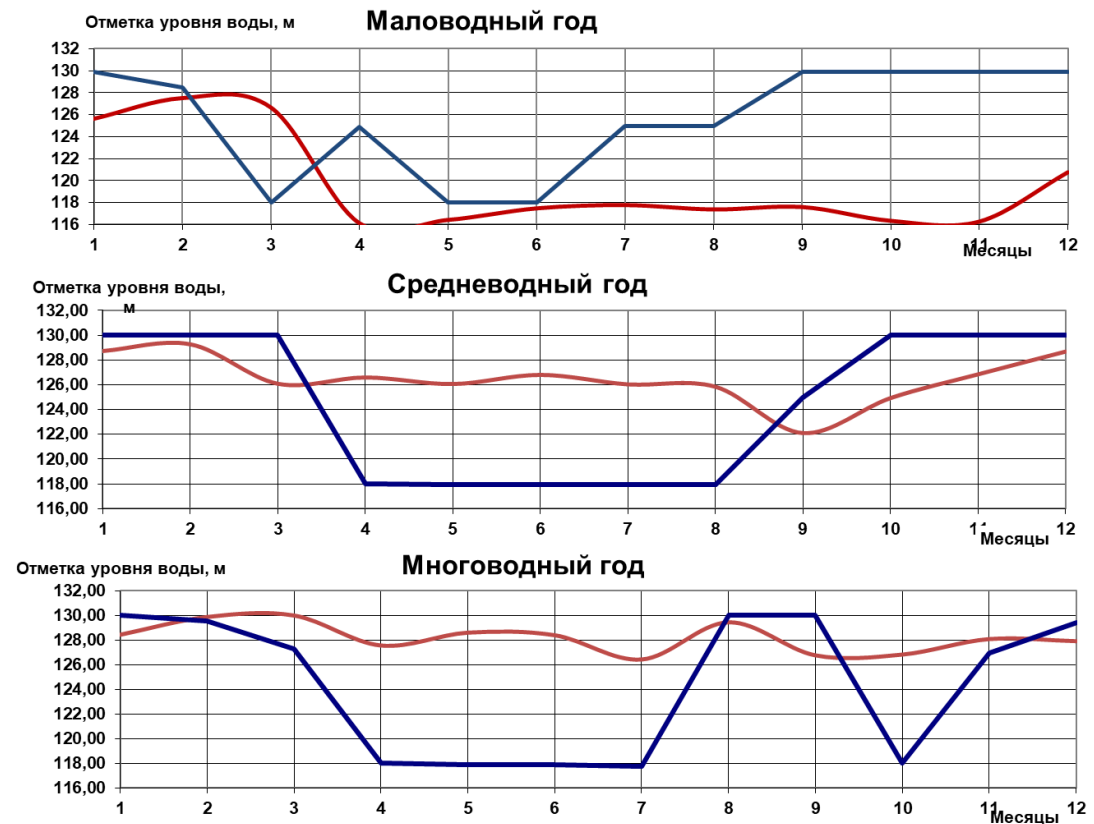
Important to maintain the sediment management efforts



An example of flushing sequence (left) and corresponding variation of discharge and sediment concentration (Annandale et al., 2016)



Proposed reservoir operation mode (M. Ikramova)



Management of sediment-induced problems at THC (26/28)

Dam heightening

Not preferable
for THC!

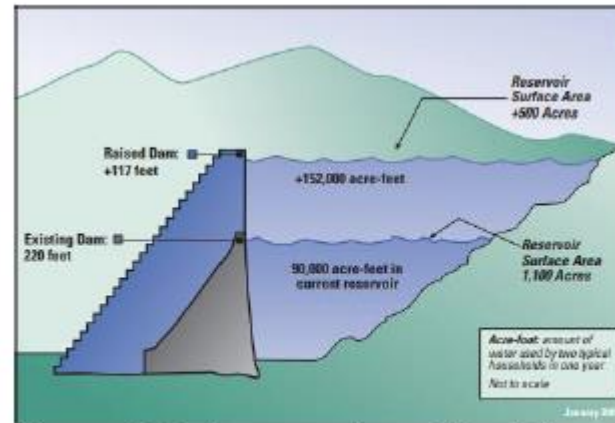


Figure 4-39. Cross-section of San Vicente dam raise (www.sdcwa.org/san-vicente-dam-raise)



Figure 4-38. Spillway raise in Papanasam forebay in Tamil Nadu, India

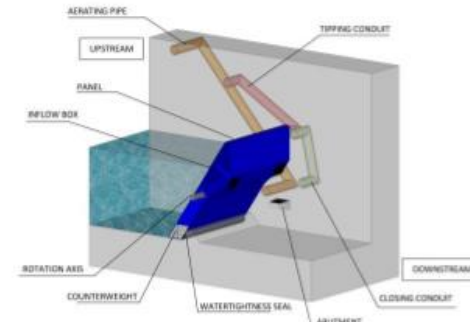


Figure 4-42. A sketch of a Smart fusegate (www.hydroplus.com)

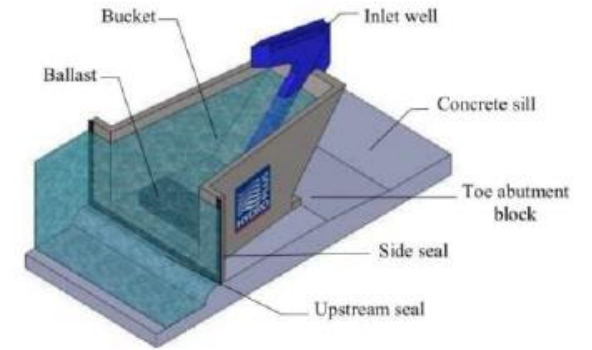


Figure 4-40. A sketch of a Classic fusegate (www.hydroplus.com)



Figure 4-43. The Fusegates in Black Rock Dam, US (upper) and Vorotna Dam, Armenia (lower) (www.hydroplus.com)



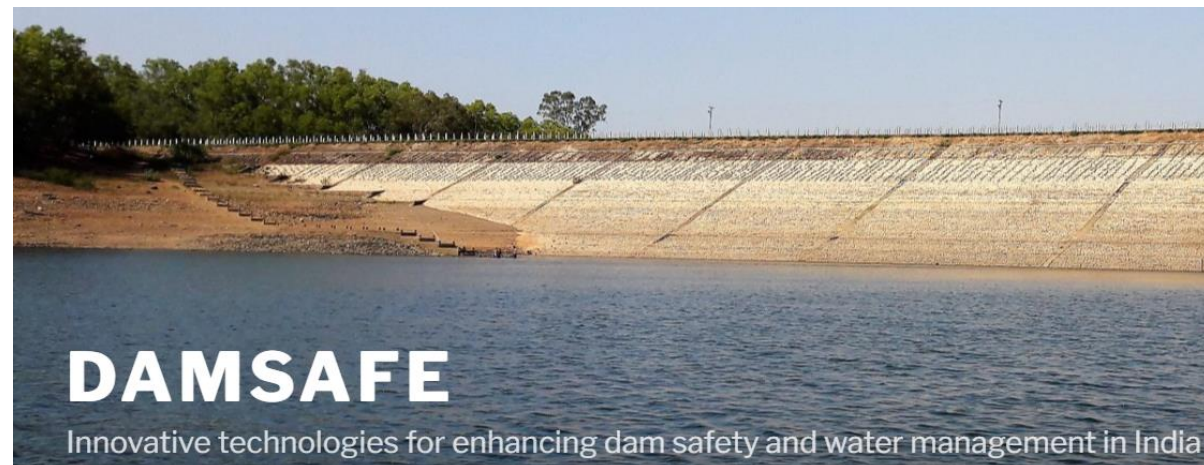
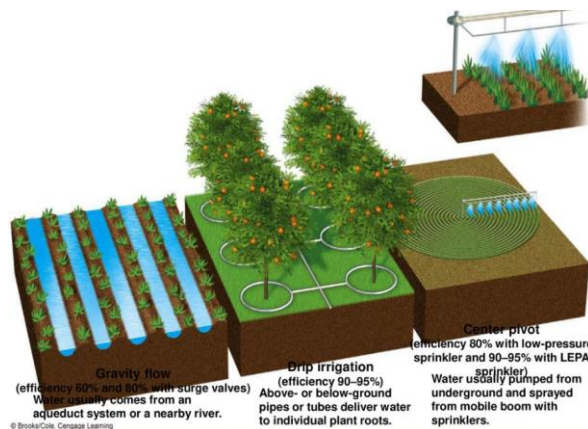
Figure 4-41. A Folding fusegate (www.hydroplus.com)

Management of sediment-induced problems at THC (27/28)

Non-structural measures

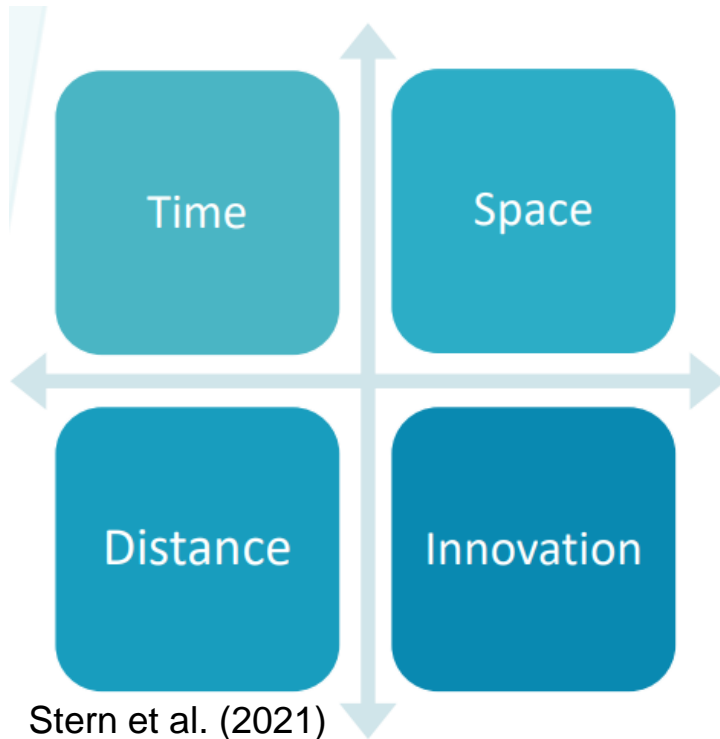
Required for future management and mitigation as well after the rehabilitation

- ✓ Improving irrigation practices and methods
- ✓ Reducing water losses at the reservoirs and canals (due to sedimentation, seepage, evaporation)
- ✓ Establishing monitoring, water information and forecasting systems
- ✓ Establish Integrated and Participatory Management (following NEXUS approach) – *this is important given that THC is a transboundary complex, and addressing the problems requires participation of all involved stakeholders, authorities and countries.*
- ✓ Investing on regular Research and Development activities



Management of sediment-induced problems at THC (28/28)

Challenges and constraints



Time - Duration, regulatory timeframe, permitting window, volume of accumulation

Space – Project-limited working site access or area to accommodate sediment processing, project logistics

Distance - Sediment disposal, beneficial use sites, transportation logistics, legal aspects

Innovation – Acceptance to innovative approach and new technology

Social, technical, environmental, economic, and legal constraints!

Transboundary disputes!

Thank you!!!

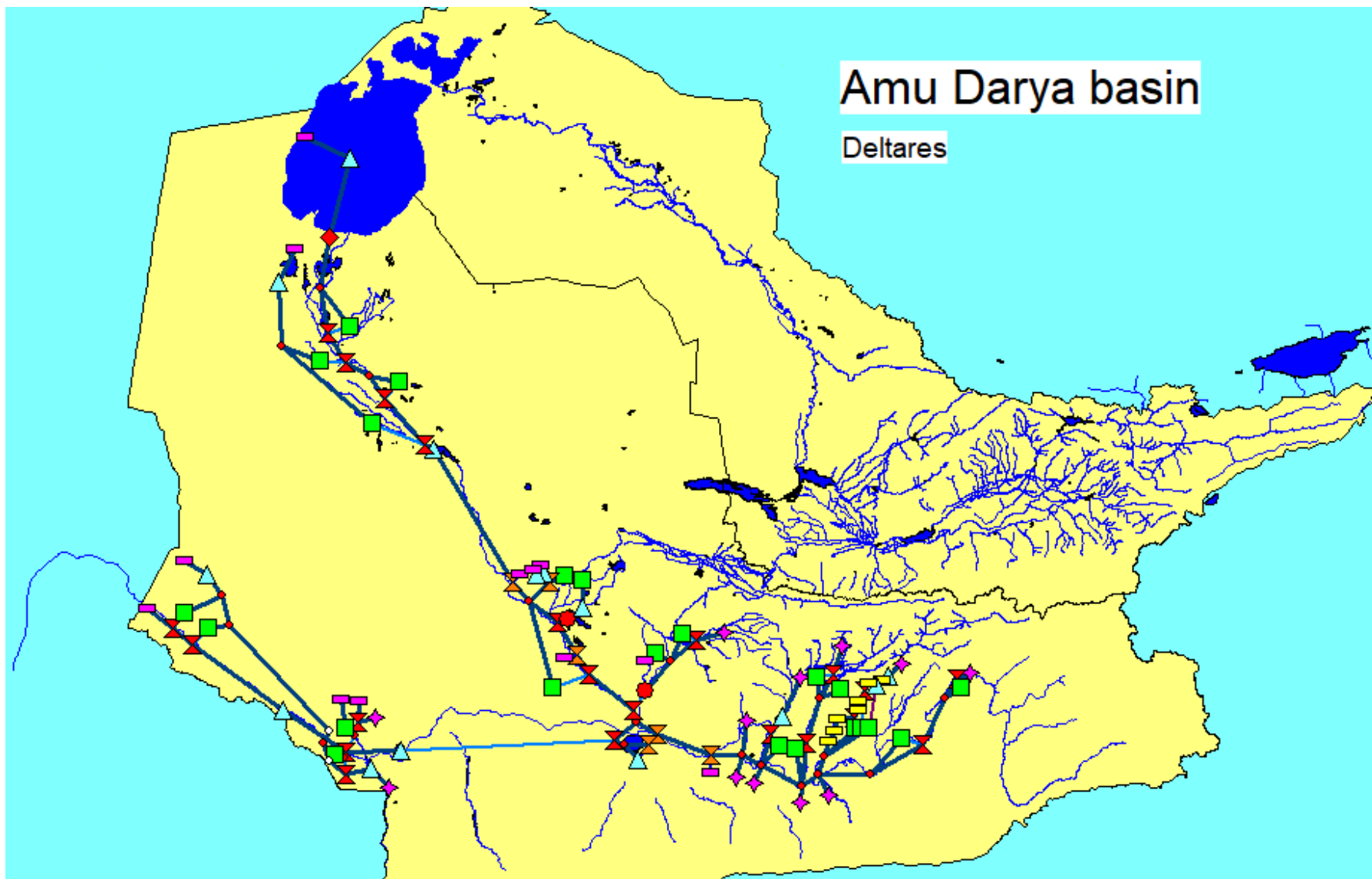
Supplementary slides

Amu Darya basin

Deltares

Nodes and links

- ◆ Variable Inflow (12)
- Confluence (20)
- Terminal (12)
- Recording (2)
- △ SW reservoir (14)
- ▬ Run-off-river (7)
- ✕ Diversion (21)
- ◆ Low Flow (1)
- Fixed Irrigation (22)
- ✕ Bifurcation (6)
- Pumping (2)
- SW flow (107)
- Diverted flow (23)
- Bifurcated flow (7)
- SW rsv backwater release (1)



Practices on beneficial reuse of sediment (1/?)



<https://youtu.be/-eMPqPHy4k0>