SEE INSIDE YOUR PROCESS

DENSE-ITOMETER

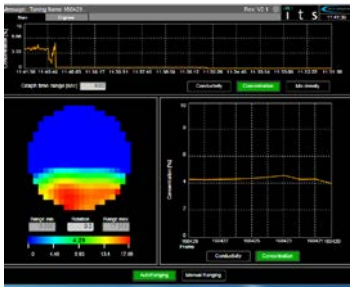
REAL TIME PRODUCTION EFFICIENCY BASED ON MEASUREMENT OF FLOW PROFILE & VELOCITY

Kent Wei, Changhua Qiu, Ken Primrose and Wadoud Hazineh

WEDA 27th June 2018

Process Tomography - a New Measurement Methodology

Combines measurements from distributed sensors to determine internal conditions



Motivation to Replace Nuclear Source

Operational benefits

- Lower cost maintenance
- Eliminates local compliance rules, regulations
- Simpler transport and installation
- Reduced whole life cost
- Additional information

CSR (Corporate responsibility and risk) benefits

- Sustainable – no nuclear source in operations
- No remainder disposal
- Eliminates risk
- Simplifies working procedures

Product History

Seven year development program with leading dredging company

Installed on four vessels and tested round world

Sensor durability demonstrated at flow rates > 30,000 tonnes / hr

Agreed roll out program in dredging fleet

ITS working with all major EU dredgers

Significant Cost Saving - Comparison 800mm Sensor

- Significant savings, particularly for larger sensors

Cost Benefit Comparison (20-year life)	Cost Nuclear		Total (nuclear)	Cost ITS Densitometer
Initial Instrument Cost	$30,000	1	$30,000	$62,000
Supplemental sources	$25,000	2	$50,000	$-
Maintenance over 20 year period	$1,200	20	$24,000	$45,000
Source registration (2 territories / year)	$4,800	20	$96,000	$-
Transport & disposal	$4,800	3	$14,400	$1,000
Total			**$214,400**	**$108,000**

STANDARD INSTALLATION LAYOUT

Layout v3: 19/01/2016
By HA

DENS-ITOMETER
(DATA ACQUISITION SYSTEM)
IP66 ENCLOSURE
110-250 Vac 50/60 Hz 10A
Power Supply
~40 Kg
H=600 x W=400 x D=350 mm

Cabinet Installation dimension (Please refer to page 4 & 5)

110-250 Vac → Isolating Transformer

3 core power cable

Meter

CONDUCTIVITY

2

3

24V dc 2 core cable
4-20mA signal out +GND

1

5

ETHERNET CABLE UP 100m

PC
(For commissioning and maintenance)

CONDUCTIVITY Probe
10 bar need to be installed into background water

σ_1 = water conductivity

DENS-ITOMETER
SENSOR*

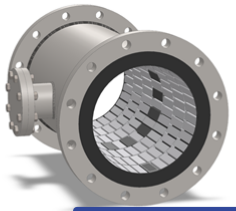
< 5 meters from Dens-itometer enclosure

4

Density output

2 core cable
4-20mA Signal out +GND
(Length: from Ship Control room to dens-itometer Instrument)

THE SHIP
CONTROL ROOM

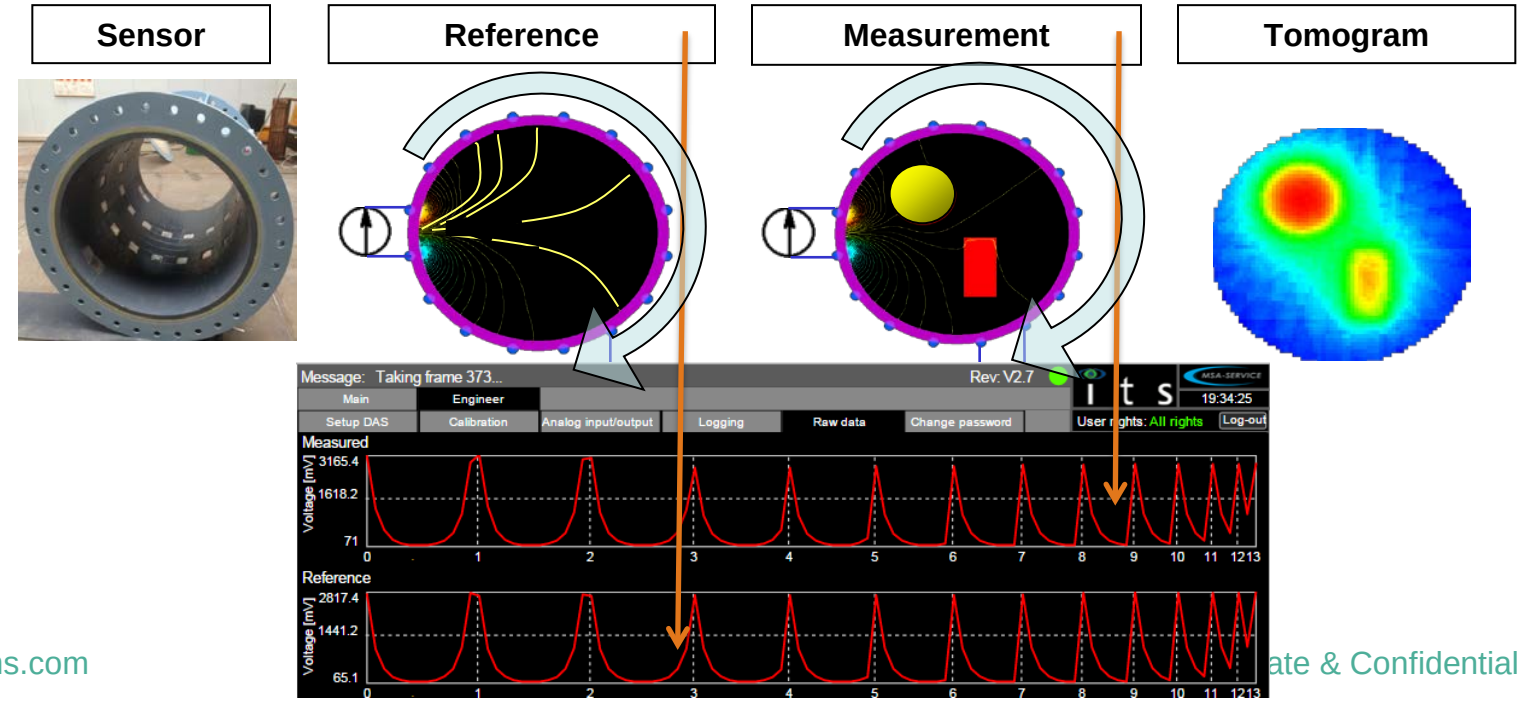


σ_{mc} = mixture conductivity

* Sensor Drawing (please refer to page 3)

Measurement Principle

- Conductivity scan across electrode array
- Compare to reference
- Algorithm to map conductivity
- Conductivity map produces solids concentration



Density Calculation

Determine % non-conductive solids with Maxwell equation:

$$\alpha = \frac{2\sigma_1 + \sigma_2 - 2\sigma_{mc} - \frac{\sigma_{mc}\sigma_2}{\sigma_1}}{\sigma_{mc} - \frac{\sigma_2}{\sigma_1}\sigma_{mc} + 2(\sigma_1 - \sigma_2)}$$

For solid / liquid system simplifies to

$$\alpha = \frac{2\sigma_1 - 2\sigma_{mc}}{\sigma_{mc} + 2\sigma_1}$$

σ_1 = water conductivity

σ_{mc} = mixture conductivity

α = volume concentration

α * [specific gravity] = density

Volume Calculation

Determine % non-conductive solids with Maxwell equation:

$$\alpha = \frac{2\sigma_1 + \sigma_2 - 2\sigma_{mc} - \frac{\sigma_{mc}\sigma_2}{\sigma_1}}{\sigma_{mc} - \frac{\sigma_2}{\sigma_1}\sigma_{mc} + 2(\sigma_1 - \sigma_2)}$$

For solid / liquid system simplifies to

$$\alpha = \frac{2\sigma_1 - 2\sigma_{mc}}{\sigma_{mc} + 2\sigma_1}$$

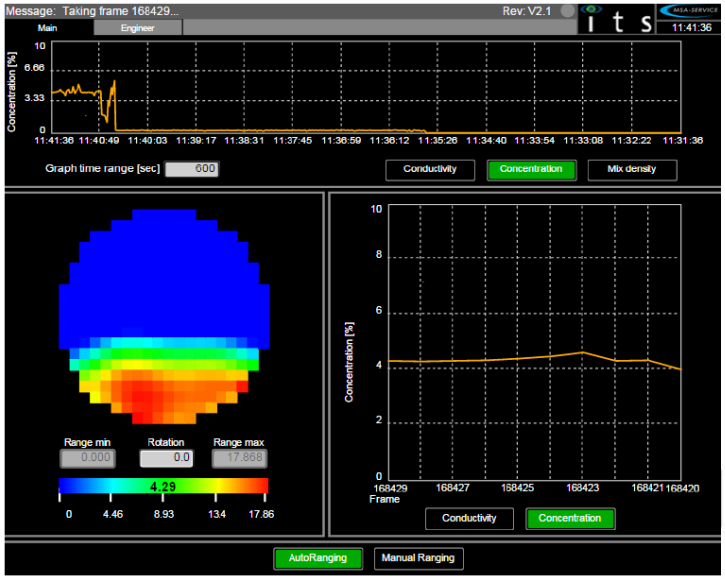
σ1 = water conductivity

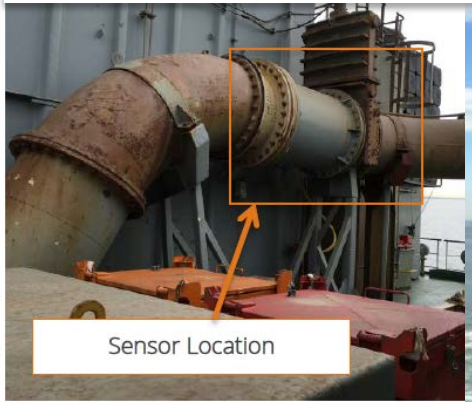
σ_{mc} = mixture conductivity

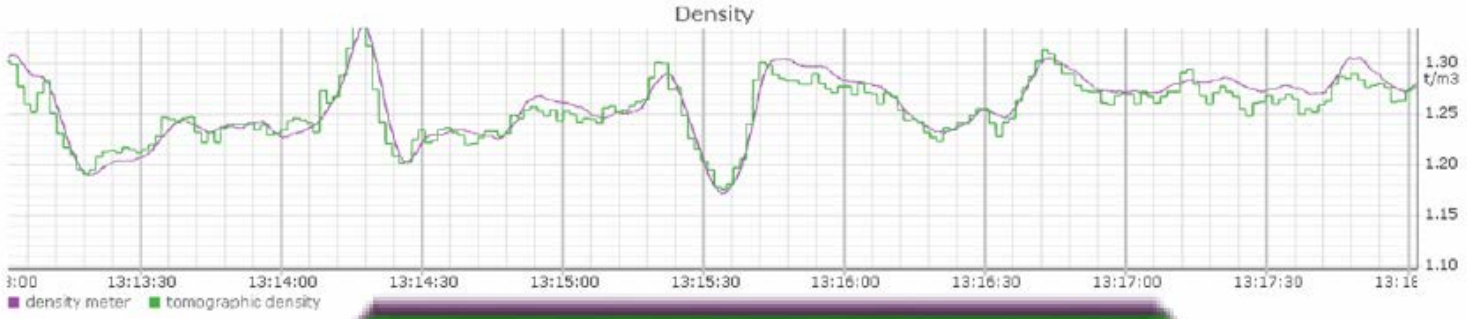
α = volume concentration

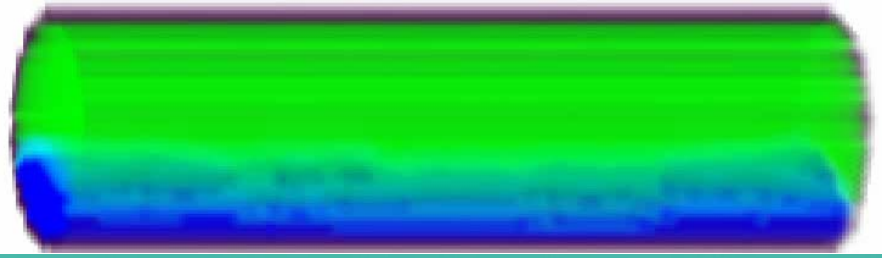
*α * [specific gravity] = density*

System Performance









System performance

Long term trials shown

- 97% agreement to gamma
- 98% agreement with Coriolis
- 99% agreement with displacement measurement

Independent of flow conditions

Measures 360º - full volume

Easy to calibrate in-line

Orientation

- Vertical
- Inclined
- Horizontal

Installations

Integrated Production Meter

Every gamma meter paired with flow meter

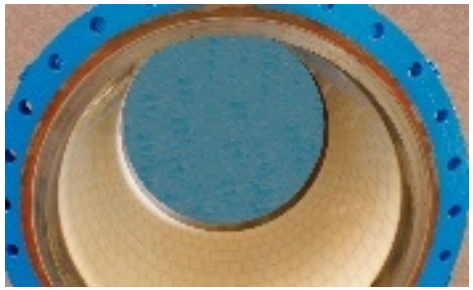
Most dredgers use mag flow

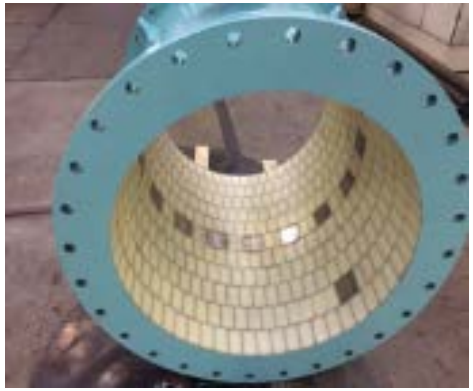
Similar measurement principle

- Electrically insulated pipe
- Measure voltage across electrode pair

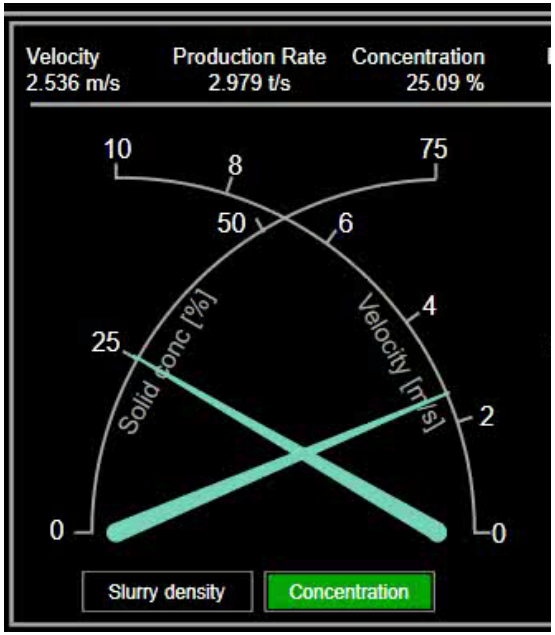
Combined sensor

- Less tiles
- Less flanges
- Shorter
- Same measurement point



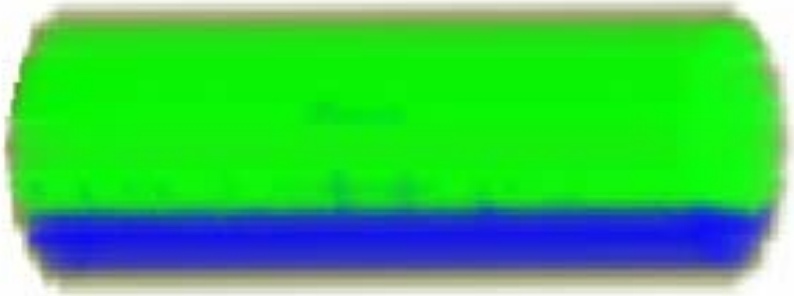


Standard Production Output

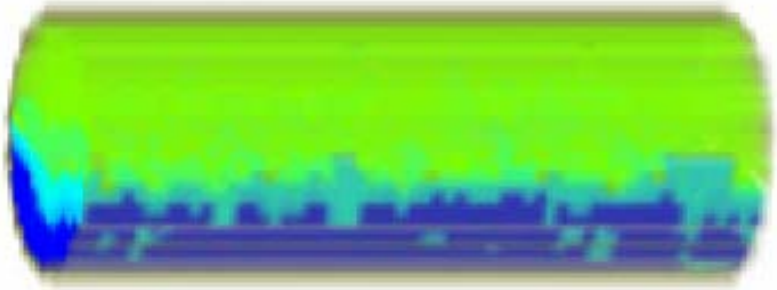


Additional Information on Flow

- Sand – median density 350 micron, up to 30% solids
- ø 150mm
- 1.5m/s



- Sand – median density 350 micron
- ø 150mm
- 6 m/s



Additional Information on Flow

Fuel represents 30% of dredge cost

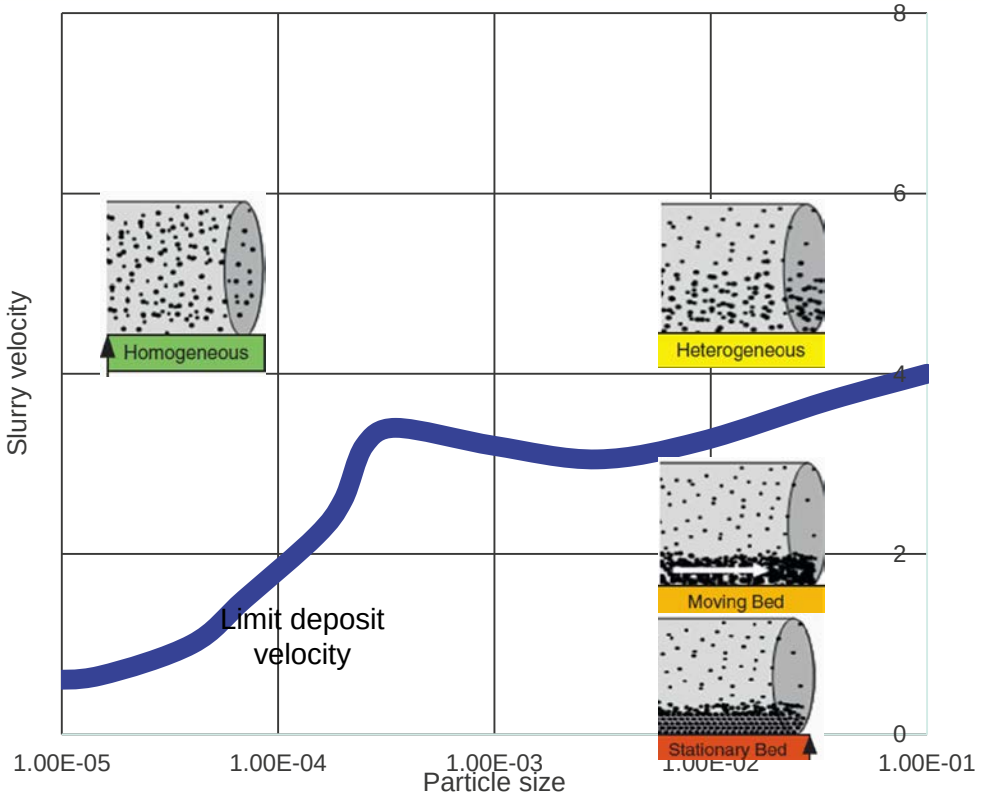
Flow regime balances

- Blockages / poor production
- Over-pumping
  - Excessive fuel cost
  - Excessive wear

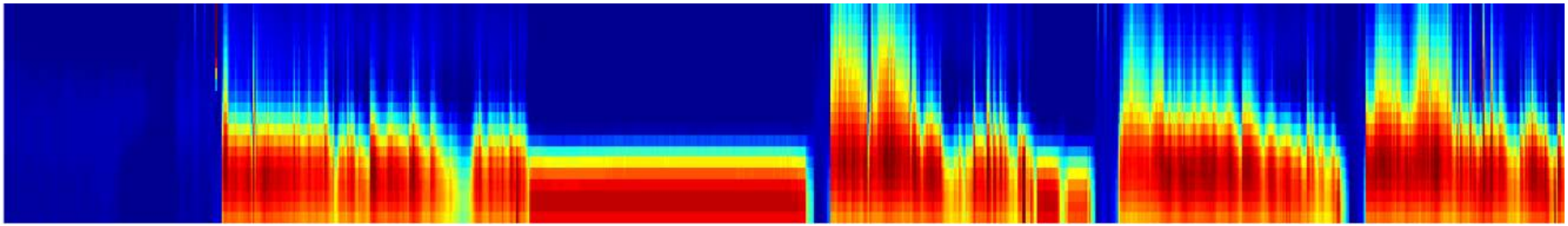
Traditionally based on

- particle size distribution (sampling)
- Limit deposition velocity

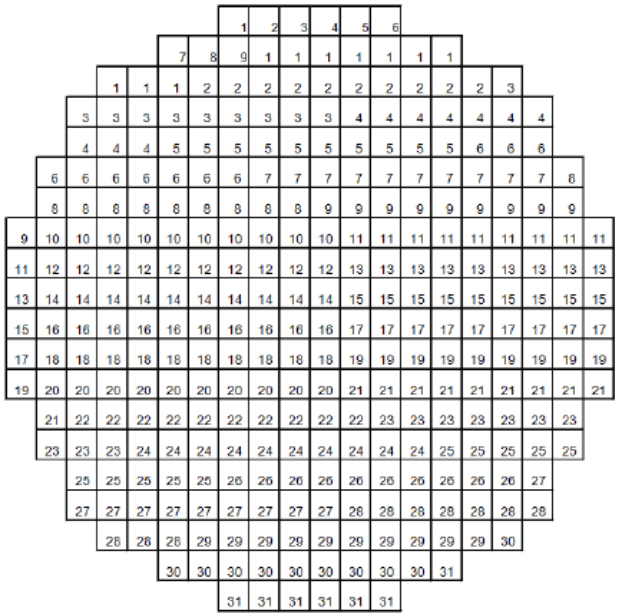
Better to use real time measurement…

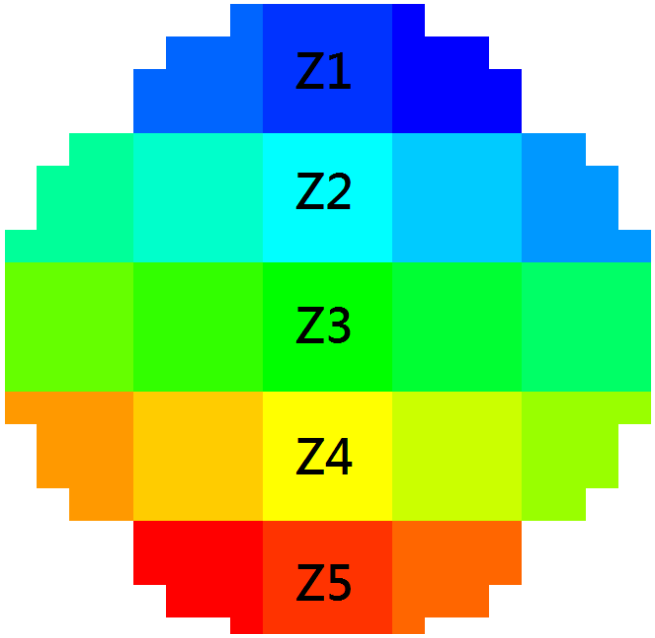


Display As 2D – Time Series



Pattern Recognition for Flow Regime (Horizontal)





$$A = \frac{Z_1 + Z_2 + \left(\frac{Z_3}{2}\right)}{3}$$

$$B = \frac{\left(\frac{Z_3}{2}\right) + Z_4 + Z_5}{3}$$

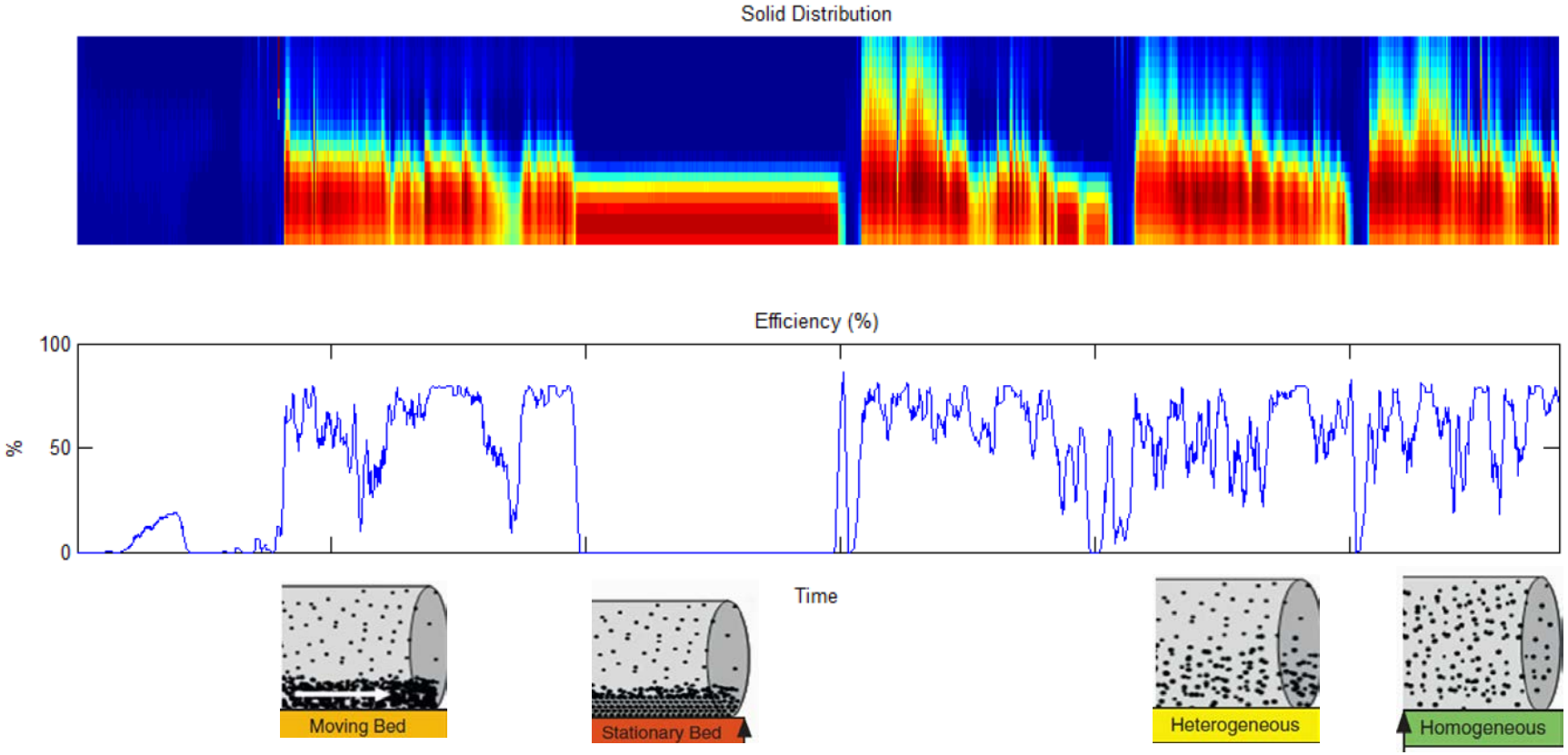
$$C = \frac{A}{(A+B)}$$

Flow Patterns

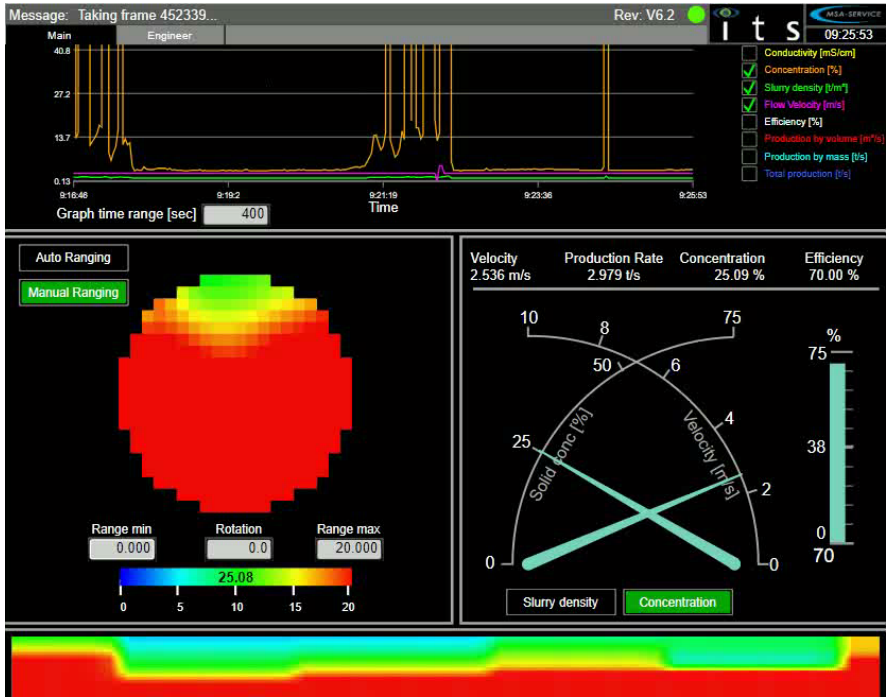
Flow condition	C range		Other measurements		Efficiency
	Min	Max	stdev [C]	% solids	
Stationary bed	0	0.55	< 0.05	> 5%	10%
Low conc. suspension	0.505	0.52	> 0.05	< 5%	20-40%
Moving bed	0	0.55	> 0.05	> 5%	40-60%
Homogenous	0.495	0.505	> 0.05	> 5%	40-60%
Heterogenous	0.52	0.55	> 0.05	> 5%	60-100%

Vertical / inclined flows require more complex efficiency model

Related "Efficiency Co-efficient"



Full User Interface



Acknowledgements

Technology Strategy Board (Innovate Grant #132793)

University of Delft (2014)

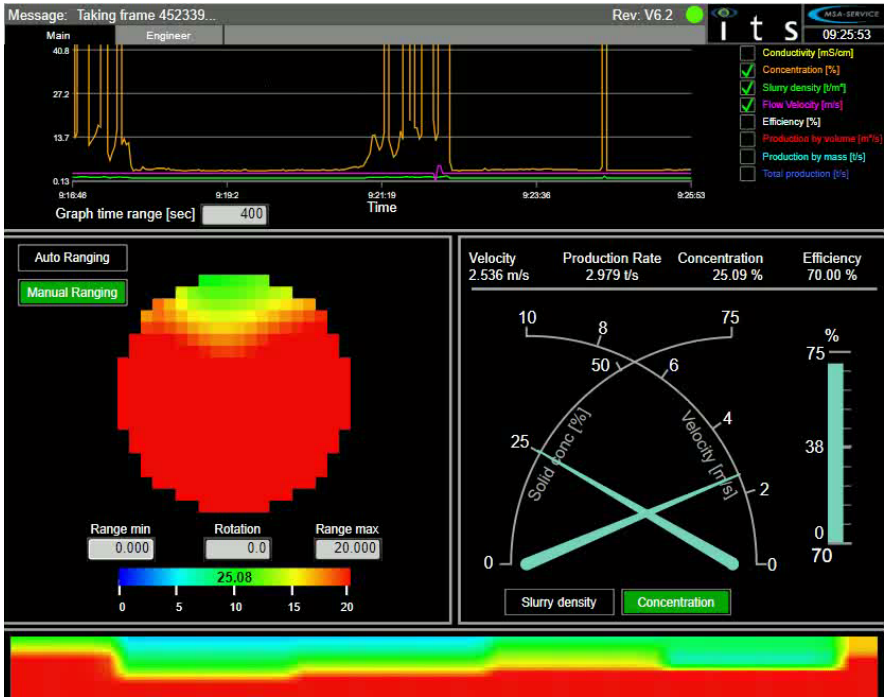
Colleagues at ITS

Input from dredging community

CONCLUSIONS

Dens-itometer

- CSR and $USD benefits
- Established processing power
  - Additional information



Integrated with magflow meter

- More compact
- Lower cost
- Integrated system

Real-time flow regime information

- Captured by tomogram
- Described through algorithm
- Additional cost savings and performance optimisation
- “% efficiency” metric – needs testing, discussion and refinement

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