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Grupo Hidromar
Hidráulica Fluvial y Marítima

PAMEC 2024
Pan American Marine Energy Conference
Barranquilla, Colombia Jan 22-24, 2024

Hydrodynamic and CFD modeling of a tidal barrage power plant in Buenaventura Colombia

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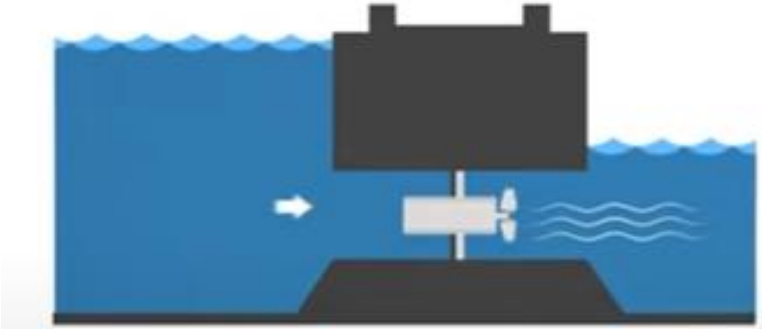
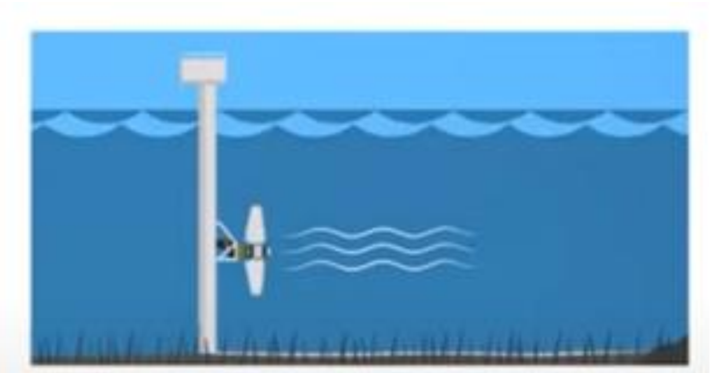
22-24 January, 2024

Tidal power technologies



Tidal range power
(barrages, dams)



Tidal stream power
(hydrokinetic turbines)

Edite from: https://www.youtube.com/watch?v=VkTRcTyDSyk

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What do we know about tidal energy in Colombia?

All related to tidal stream energy in the Colombian Pacific

2023

infrastructures MDPI

Article

Effect of Sea Level Rise and Access Channel Deepening on Future Tidal Power Plants in Buenaventura Colombia

Juan Gabriel Rueda-Bayona [1,2,*], José Luis García Vélez [1,2] and Daniel Mateo Parrado-Vallejo [1,2]

2016

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

ELSEVIER

Assessment of the marine power potential in Colombia

A.F. Osorio [a], Santiago Ortega [b], Santiago Arango-Aramburo [c,*]

2021

INGE CUC, Vol. 17, No. 2, Julio – Diciembre, 2021 (IN PRESS)

Tidal Energy Potential in the Center Zone of the Colombian Pacific Coast

DOI: http://doi.org/10.17981/ingecuc.17.2.2021.07

Artículo de Investigación Científica. Fecha de Recepción: 09/10/2020. Fecha de Aceptación: 07/11/2020

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2008

Potencial de generación de energía a lo largo de la costa colombiana mediante el uso de corrientes inducidas por mareas

Tidal Current Potential for Energy Generation along the Colombian Coastline

Recibido 29 de septiembre de 2008, aprobado 13 de enero de 2008, modificado 22 de enero de 2009.

John M. Polo

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Tidal range power in the Colombian Pacific?

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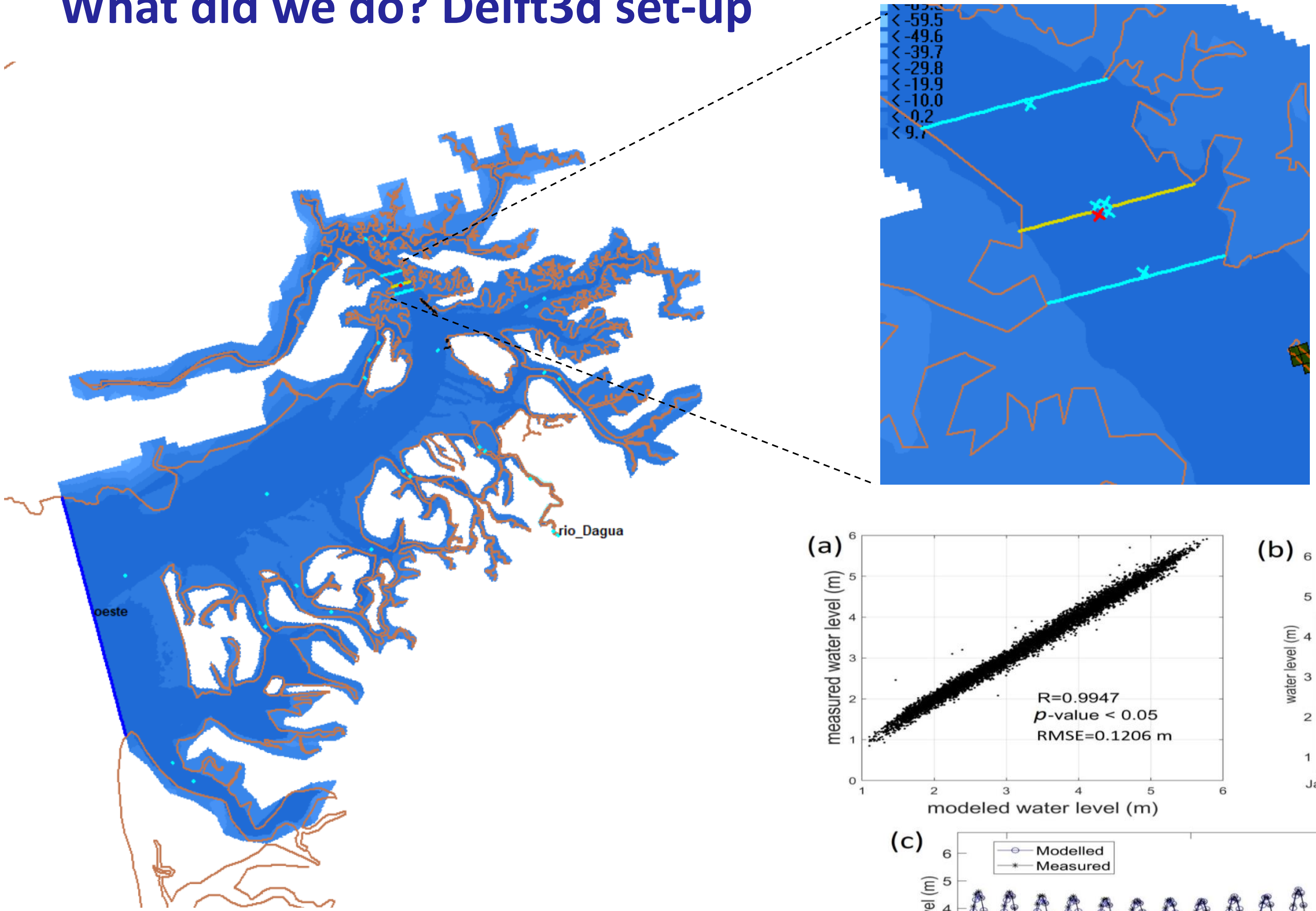
What did we do?

start

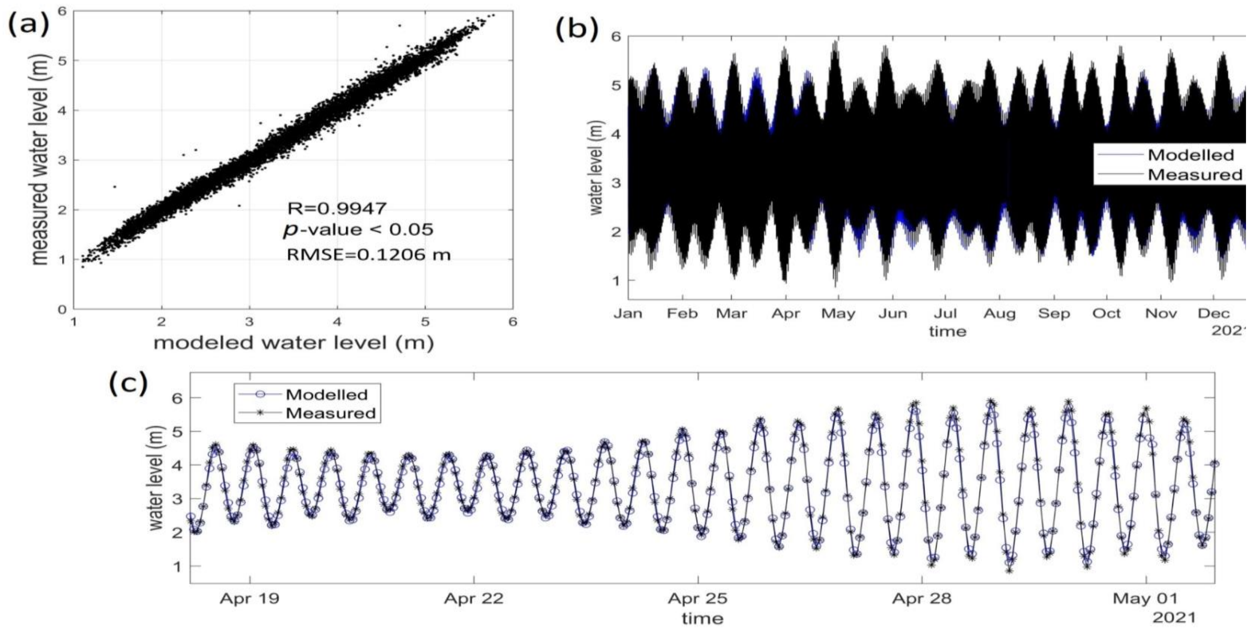
1. Identify highest Sizigy, lowest Quadrature and Stoa.
2. Calibrate and validate of 3D hydrodynamic model (Delft3D).
3. Provide generated water levels, flows and velocity currents by Delft3D to CFD model (Autodesk).
4. Set-up CFD model.
5. Validate of CFD results of flow and velocities across the chambers against theoretical equation of hydraulic drowned gate discharges.
6. Calculate available power and annual energy production using current velocity of the flow at the chambers.
7. Compare the calculated power against now operating plants.

end

What did we do? Delft3d set-up



We use the calibrated-validated Delft3d model in Rueda-Bayona et al, 2023 and Set monitoring points and cross sections.



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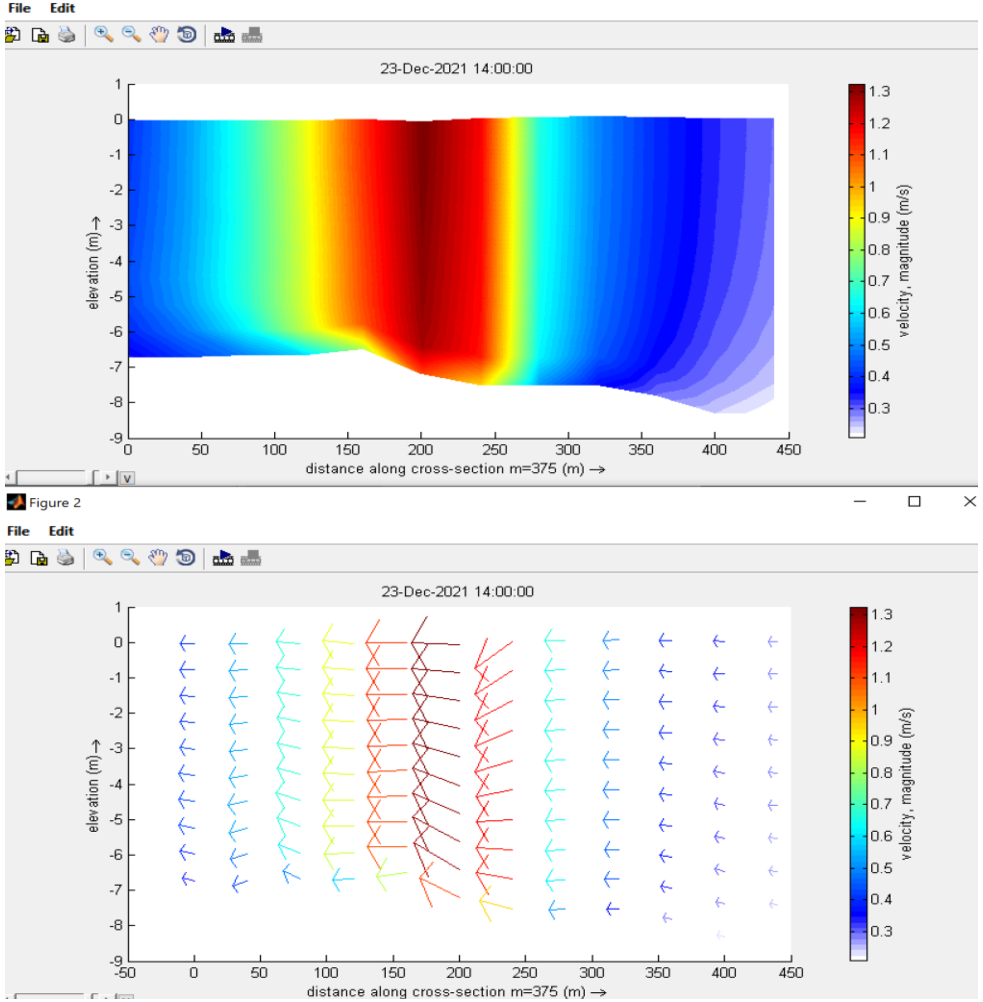
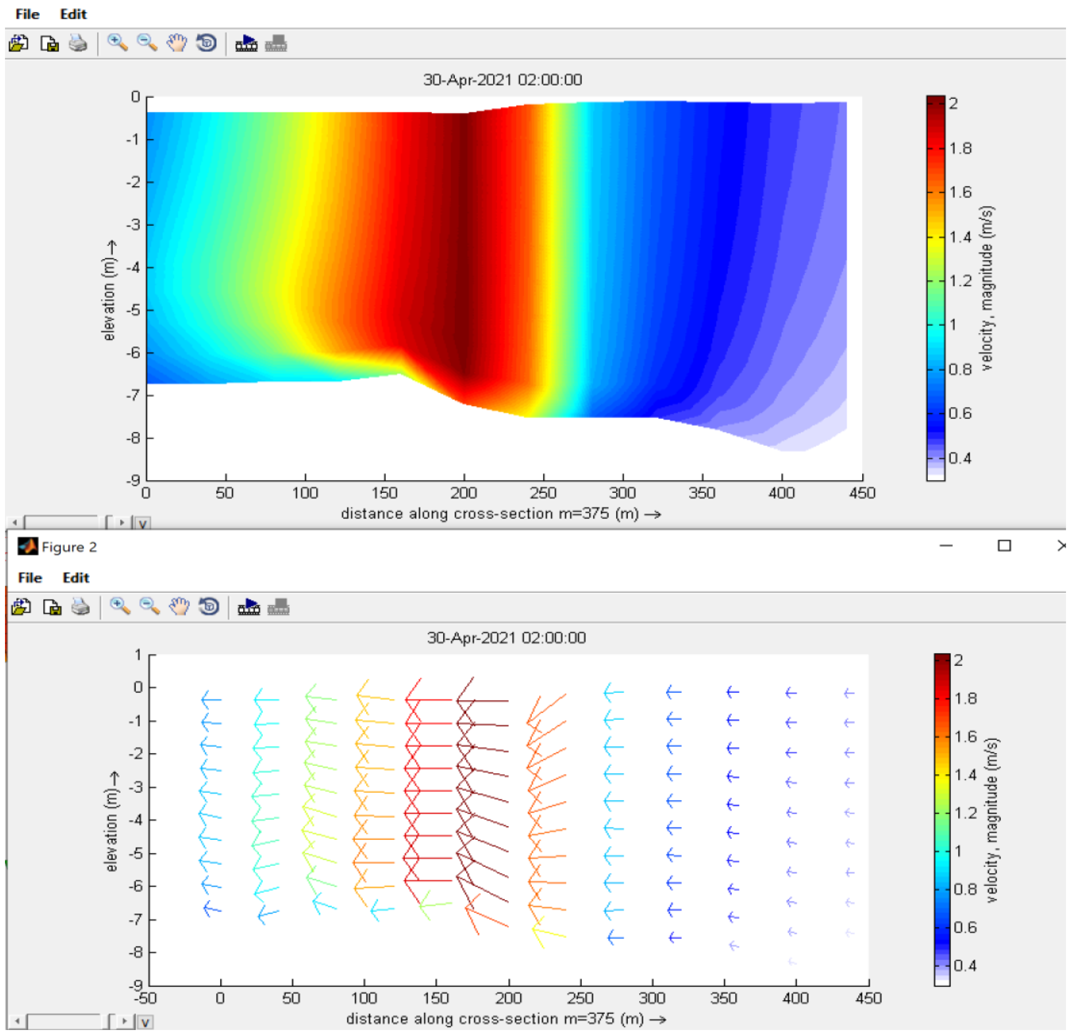
What did we do?

Deflt3D results at across the tidal barrages

Quadrature



Sicigy



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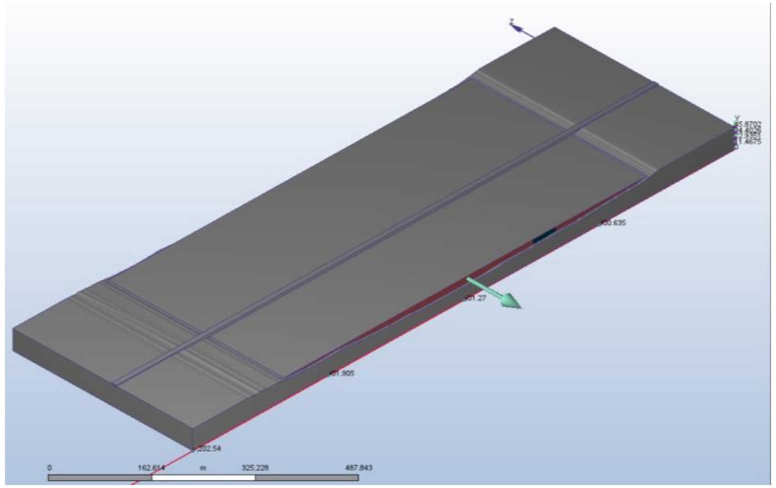
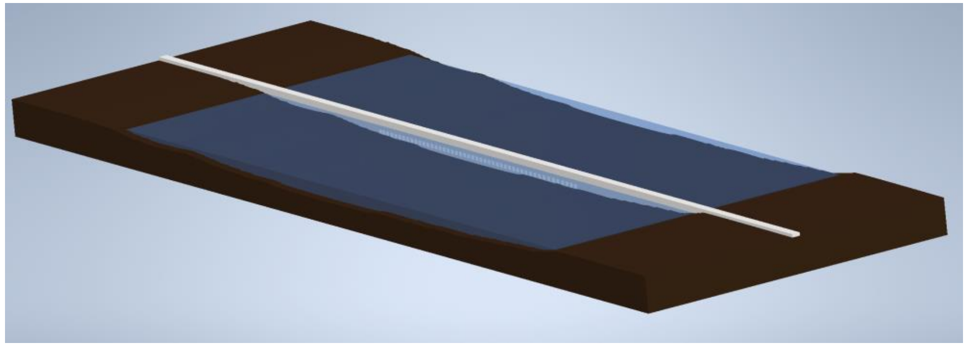
What did we do?

We took the flow and velocities measured at the cross sections of Delft3D to provide the initial conditions of the Autodesk CFD model.



Geometry of the CFD model



Cases		Flow at north cross section (m^3/s)	Flow at south cross section (m^3/s)	Velocity at north cross section (m/s)	Flow at south cross section (m/s)
Quadrature	Flood tide	530	650	0.14	0.48
	Ebb tide	565	720	0.15	0.16
Syzygy	Flood tide	768	936	0.16	0.54
	Ebb tide	797	1015	0.44	0.18
Stoa		85	107	0.04	0.02

CFD modelling cases	Date and time
Highest Sizigy	29-Apr-2021 00:00h
Lowest Quadrature	22-Dec-2021 14:00h
Stoa	22-Dec-2021 17:00h

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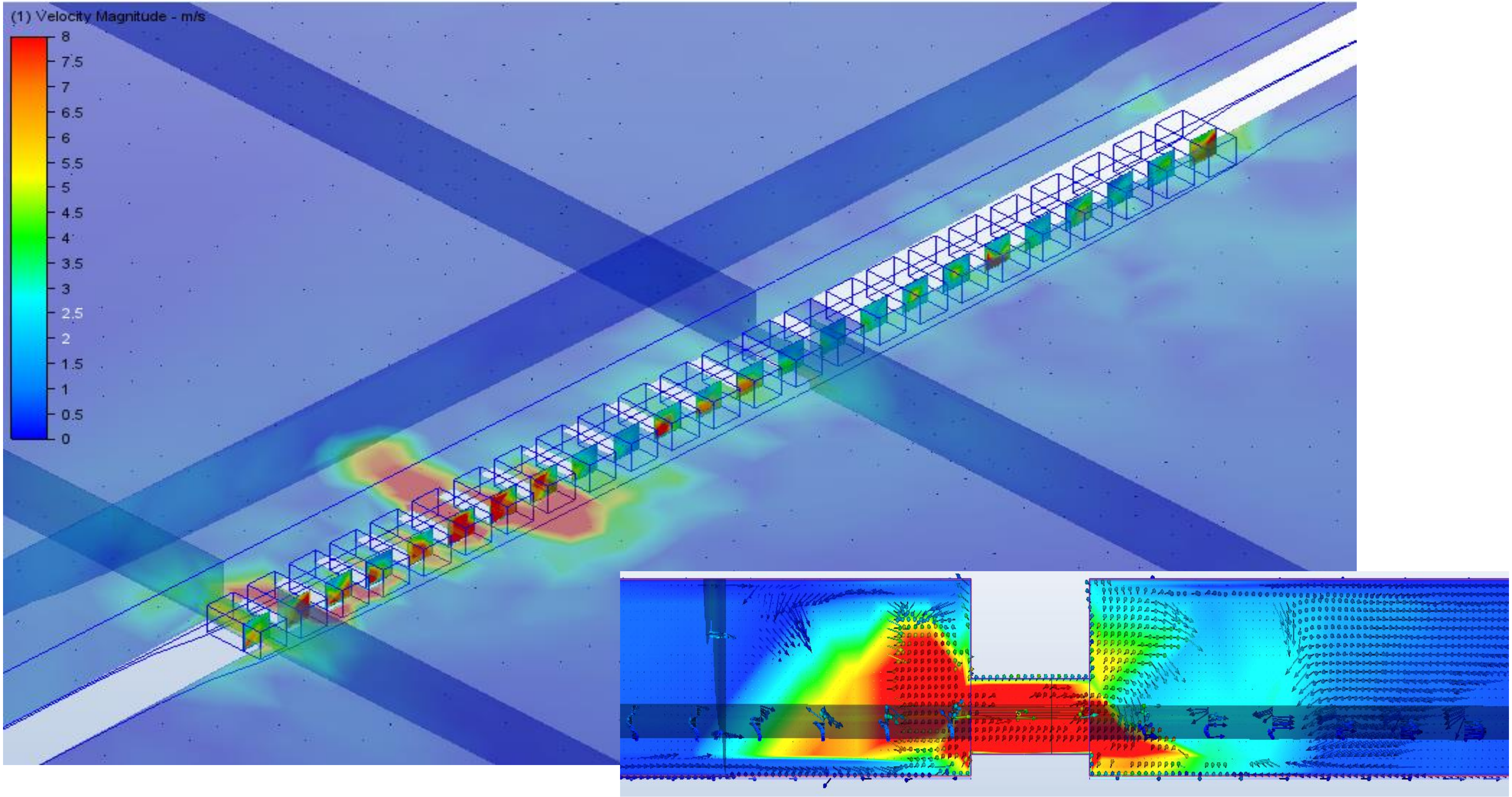
What did we do?

CFD results at across the tidal barrages



What did we do?

$$\Delta H := 3.5\ m$$

$$g := 9.81\ \frac{m}{s^2}$$

$$Cc := 0.72$$

$$y1 := 11.2\ m$$

$$a := 4.5\ m$$

$$b := 4.5\ m$$

$$A := a \cdot b = 20.25\ m^2 \quad \text{(gate area)}$$

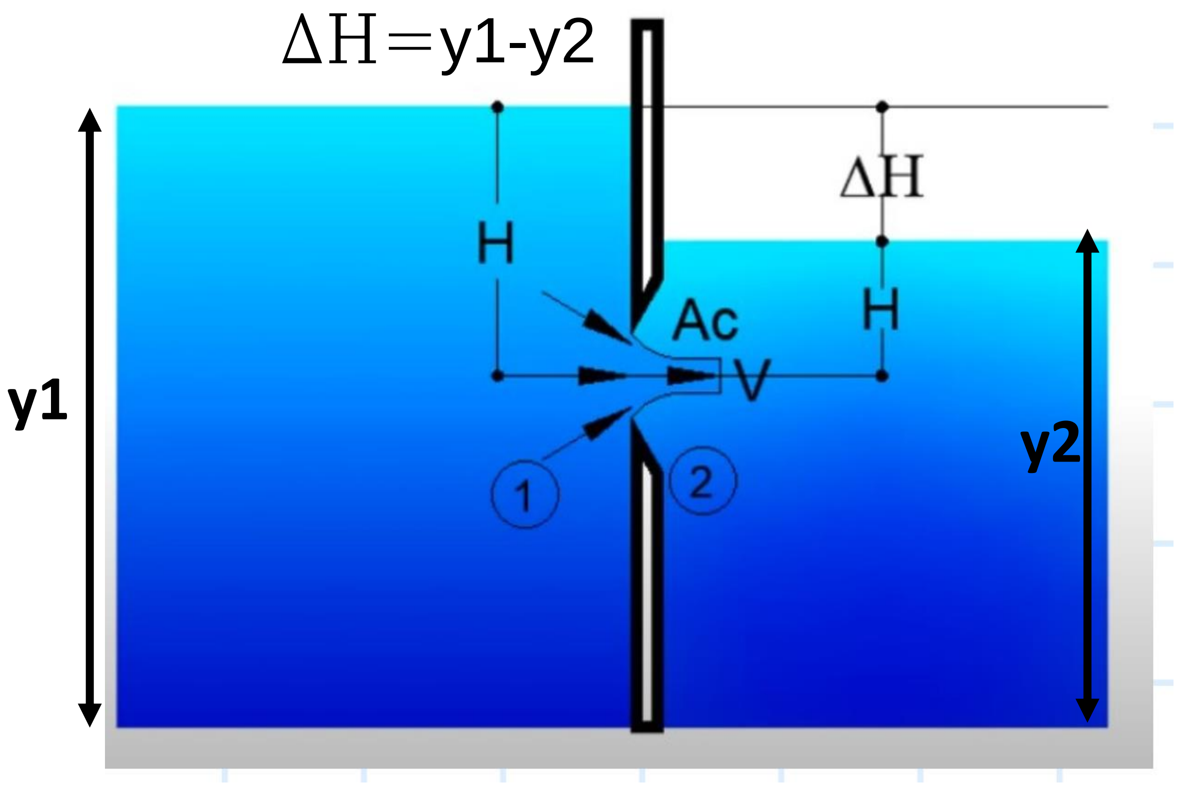
$$Cv := 0.96 + 0.079\ \frac{a}{y1} = 0.992$$

$$Cd := \frac{Cc \cdot Cv}{\sqrt{1 + \frac{Cc \cdot a}{y1}}} = 0.629$$

$$Q := Cd \cdot A \cdot \sqrt{2 \cdot g \cdot H} = 129{,}06\ \frac{m^3}{s}$$

$$V := \frac{Q}{A} = 5{,}160\ \frac{m}{s}$$

theoretical velocity at gate area close to CFD results



CFD velocities

		Velocity (m/s)																							
Gate		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Lowest Quadrature	Flood tide	4.0	4.0	4.0	6.0	5.5	5.5	5.5	5.6	6.0	6.0	6.0	5.8	5.7	5.4	4.0	4.0	4.0	4.0	4.0	3.5	3.2	3.2	3.2	3.2
	Ebb tide	4.4	4.1	4.0	4.0	3.6	3.8	2.6	2.7	2.7	2.6	2.6	2.7	3.2	3.0	3.4	3.5	3.6	3.8	3.6	3.8	3.8	3.8	3.9	3.9
Stoa		1.3	1.3	1.4	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.5	1.5	1.4	1.3	1.3	1.3	1.3	1.3
Highest Syzygy	Flood tide	5.5	6.0	6.0	5.5	5.5	5.5	6.5	5.5	5.5	6.5	6.5	6.5	6.5	4.5	4.5	4.5	4.5	4.0	3.2	2.2	2.2	2.2	3.2	3.2
	Ebb tide	7.5	6.5	4.2	5.5	4.5	6.5	6.5	4.3	4.3	4.3	6.8	6.8	7.2	4.3	4.3	6.5	8.2	11.0	7.0	7.5	6.8	6.8	7.5	4.5

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What did we do?

$$Q := Cd \cdot A \cdot \sqrt{2 \cdot g \cdot H} = 129{,}06 \; \frac{m^3}{s}$$

theoretical flow at gate area close to CFD results

		Flow (m3/s)																							
Gate		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Lowest Quadrature	Flood tide	80	80	80	120	110	110	110	112	120	120	120	116	114	108	80	80	80	80	80	70	64	64	64	64
	Ebb tide	88	82	80	80	72	76	52	54	54	52	52	54	64	60	68	70	72	76	72	76	76	76	78	78
Stoa		26	26	28	32	34	34	34	34	34	34	34	34	34	34	34	34	30	30	28	26	26	26	26	26
Highest Syzygy	Flood tide	110	120	120	110	110	110	130	110	110	130	130	130	130	90	90	90	90	80	64	44	44	44	64	64
	Ebb tide	150	130	84	110	90	130	130	86	86	86	136	136	144	86	86	130	164	220	140	150	136	136	150	90

		Power (MW)																							
Gate		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Lowest Quadrature	Flood tide	4.3	4.3	4.3	6.4	5.9	5.9	5.9	6.0	6.4	6.4	6.4	6.2	6.1	5.8	4.3	4.3	4.3	4.3	4.3	3.8	3.4	3.4	3.4	3.4
	Ebb tide	4.7	4.4	4.3	4.3	3.9	4.1	2.8	2.9	2.9	2.8	2.8	2.9	3.4	3.2	3.6	3.8	3.9	4.1	3.9	4.1	4.1	4.1	4.2	4.2
Stoa		0.7	0.7	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7
Highest Sizygy	Flood tide	8.8	9.6	9.6	8.8	8.8	8.8	10.4	8.8	8.8	10.5	10.5	10.5	10.5	7.2	7.2	7.2	7.2	6.4	5.1	3.5	3.5	3.5	5.1	5.1
	Ebb tide	12.1	10.5	6.8	8.8	7.2	10.5	10.5	6.9	6.9	6.9	10.9	10.9	11.6	6.9	6.9	10.5	13.2	17.7	11.3	12.1	10.9	10.9	12.1	7.2

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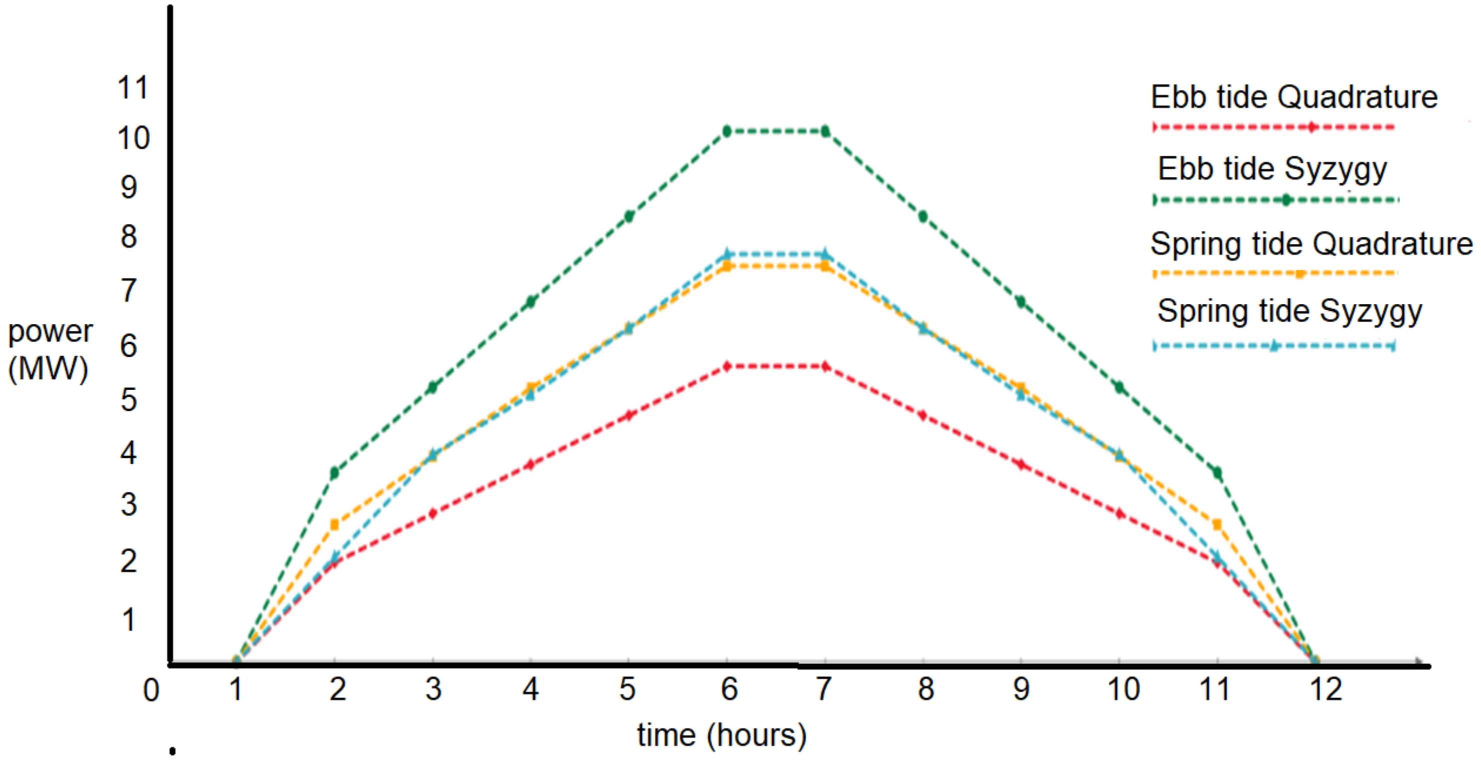
What did we do?



Gate		Mean power of 1 turbine (MW)	Mean power by 24 tubines (MW)
Lowest Quadrature	Spring tide	5.0	119.2
	Ebb tide	3.7	89.0
Stoa		0.8	19.7
Highest Sizygy	Spring tide	7.7	185.9
	Ebb tide	10.0	240.0
Mean		5.44	130.7

Conclusions

Parameter	Buenaventura	La Rance	Sihwa	Jiangxia	Annapolis	Kislaya Guba
Tidal range (m)	3.7	11	9.8	5.1	6.4	2.3
Turbines	24	24	10	6	1	1
Power by 1 turbine (MWh)	5.45	10	26	3.9	20	1.7
Total installed capacity (MWh)	130.8	240	260	23.4	20	1.7

1. **Theoretically, at the estuary of Aguadulce in Buenaventura Bay, exist the potential to produce 130.8 MWh with 24 bulb turbines.**
2. **The found power potential might increase with hydraulic optimization of chambers, gates and the capacity factor of bulb turbines (e.g Andritz turbines).**
3. **There exist others estuary pending for evaluation which could increase the tidal range power potential in Buenaventura Bay.**
4. **The Buenaventura tidal range plant could be the 3rd worldwide in energy production.**

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Thank you

https://bepacific.co/producto/tour-cali-es-salsa/

https://www.infobae.com/america/colombia/2022/09/01/cali-recibio-fue-destacada-como-destino-ciudad-cultural-lider-de-sudamerica/

https://i.ytimg.com/vi/heQw9P3dW90/maxresdefault.jpg

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