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Docket Number:	24-SB-605
Project Title:	SB 605 Wave and Tidal Energy - Phase 2
TN #:	262567
Document Title:	Presentation - Wave and Tidal Energy Resource
Description:	April 2 Workshop Presentation 2 - Integral Consulting
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Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	4/2/2025 4:06:48 PM
Docketed Date:	4/2/2025

Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits

SB 605 Report

Phase 2 - Chapter 1 and 2 slides

April 2, 2025

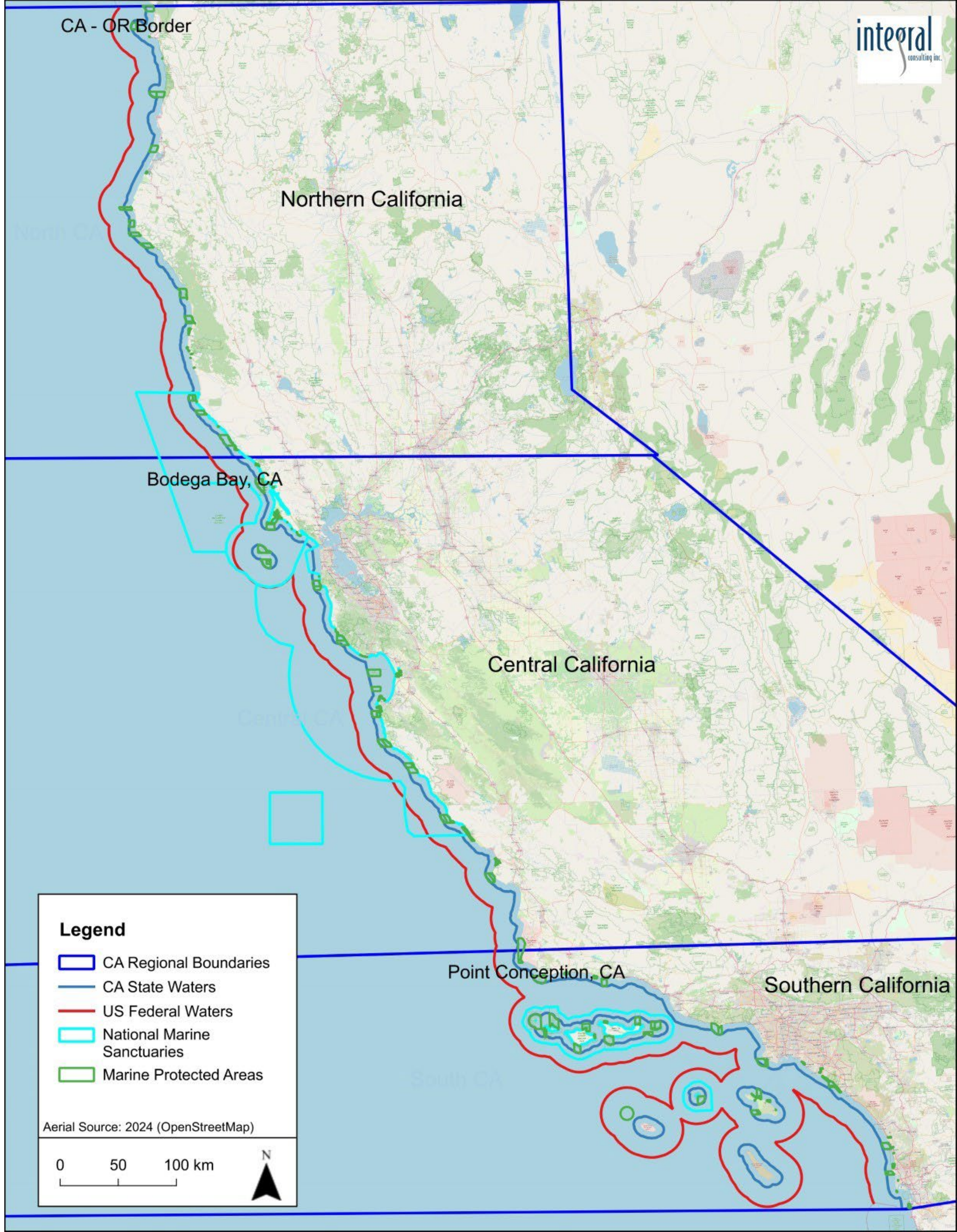
Chapter 1 Objectives

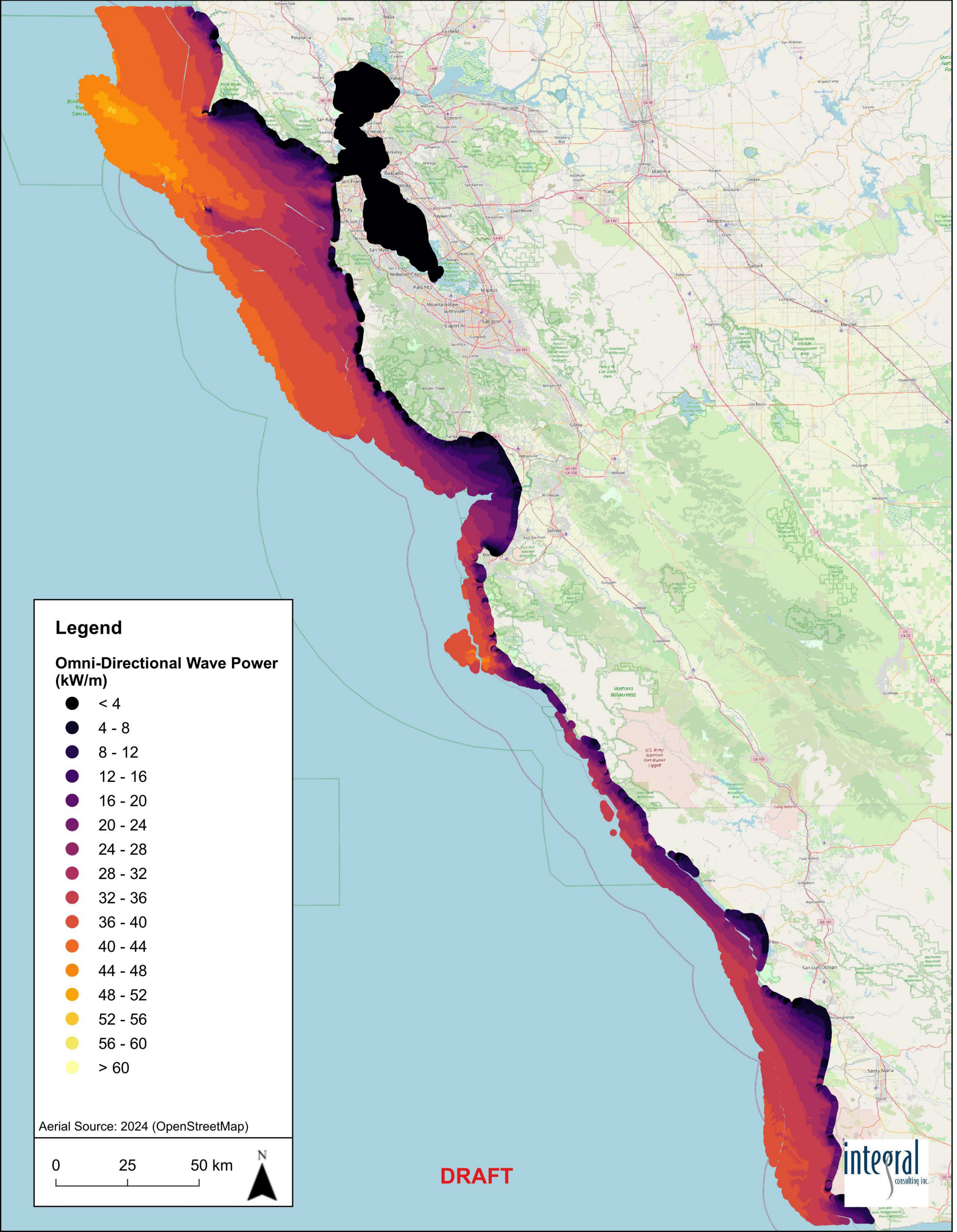
- Map energy resource availability and conduct initial spatial planning review
- Using existing data layers, identify:
  - Areas with greatest potential resource
  - Degree of overlap with other marine uses
    - Potential conflicts (detailed review in Chapter 3)
    - Potentially supporting uses (more detail in Chapter 2)
- Device agnostic
  - Not designed to pick locations for individual applications
- Areas identified in this report do not constitute support for, or opposition to, any individual project or location

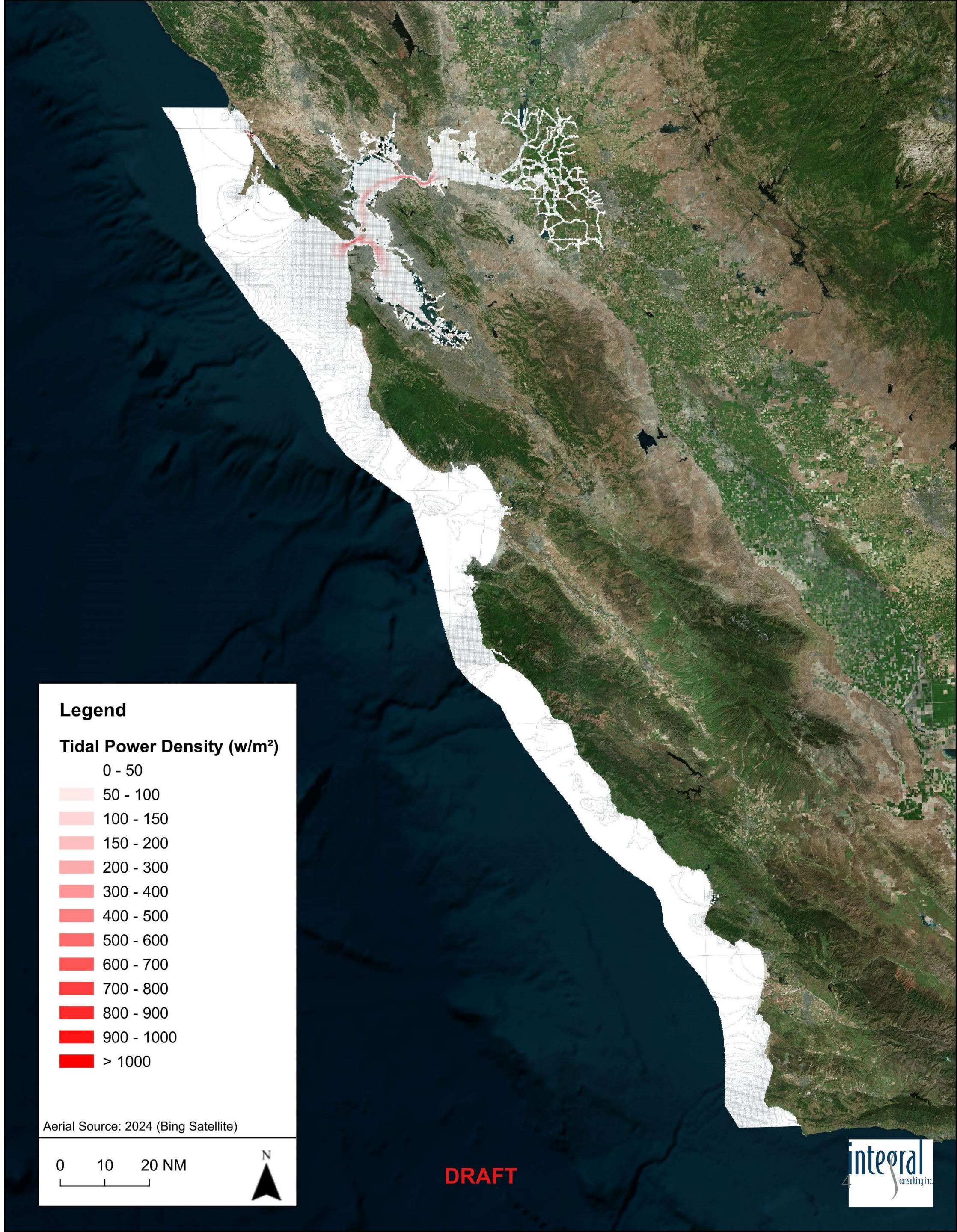
Data Analysis and Reporting

› California separated into three regions: Southern, Central, Northern
  - Southern California (from the Mexico border north to Point Conception)
  - Central California (from Point Conception north to Bodega Bay)
  - Northern California (from Bodega Bay north to the Oregon border)

› Reflect differences in energy resource availability, population centers, and marine ecosystems




Legend
Omni-Directional Wave Power (kW/m)
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
32 - 36
36 - 40
40 - 44
44 - 48
48 - 52
52 - 56
56 - 60
> 60
Aerial Source: 2024 (OpenStreetMap)
0
25
50 km
N
DRAFT
integral consulting inc.


Legend
Tidal Power Density (w/m²)
0 - 50
50 - 100
100 - 150
150 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1000
> 1000
Aerial Source: 2024 (Bing Satellite)
0
10
20 NM
N
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Tidal and Wave Energy Geoprocessing

Tidal Energy Data — Grid Cells

Wave Energy Data — Point Data

- Split into Regions → Summarized energy potential by region
- Sort into Bands → Created new layers with energy bands
- Overlay with Bathymetry → Summarized depth and distance in each energy band
- "Overlap Analysis" with Constraining Areas → Calculated share of each energy bin that does/does not overlap with constraint layer

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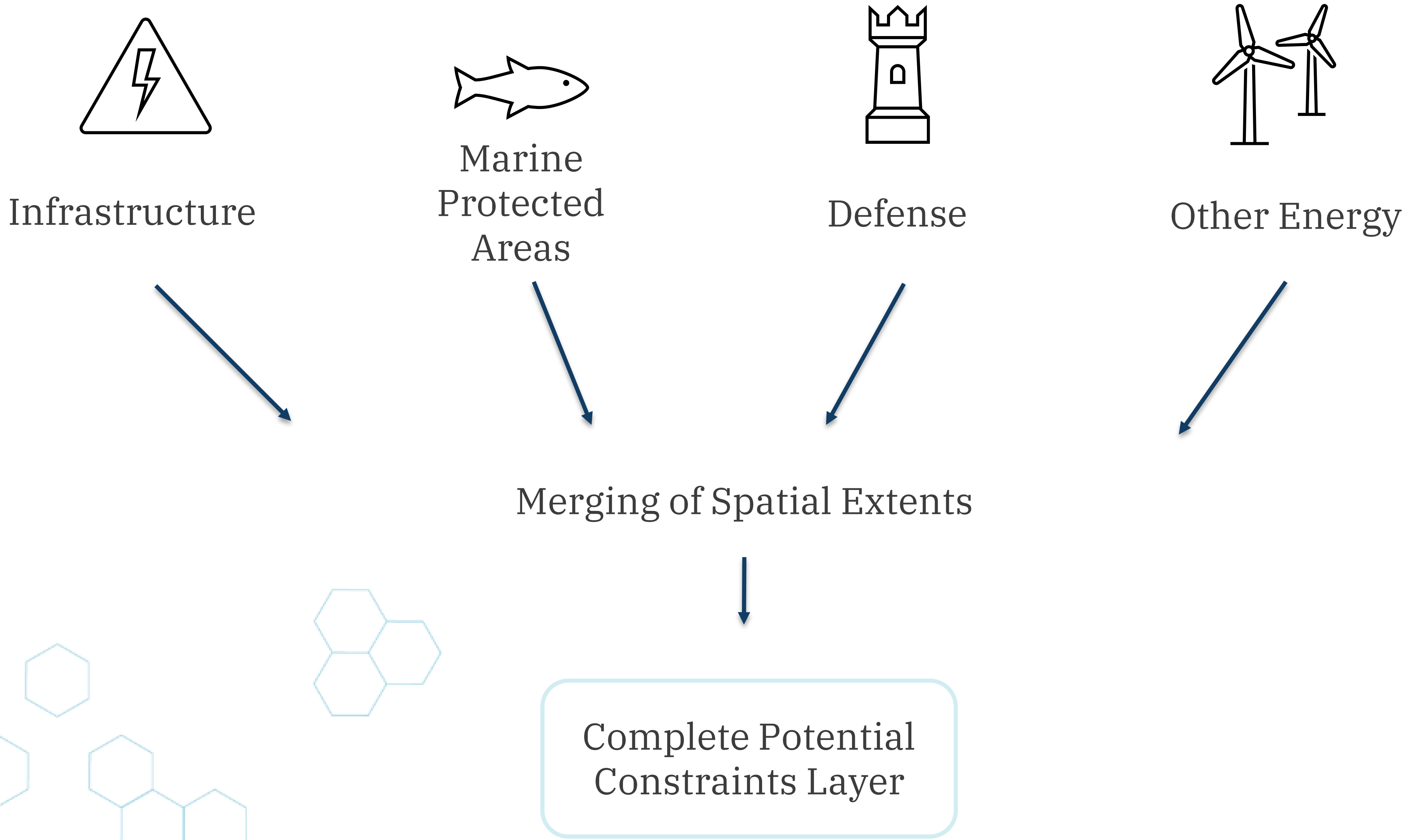
Spatial Constraint Analysis



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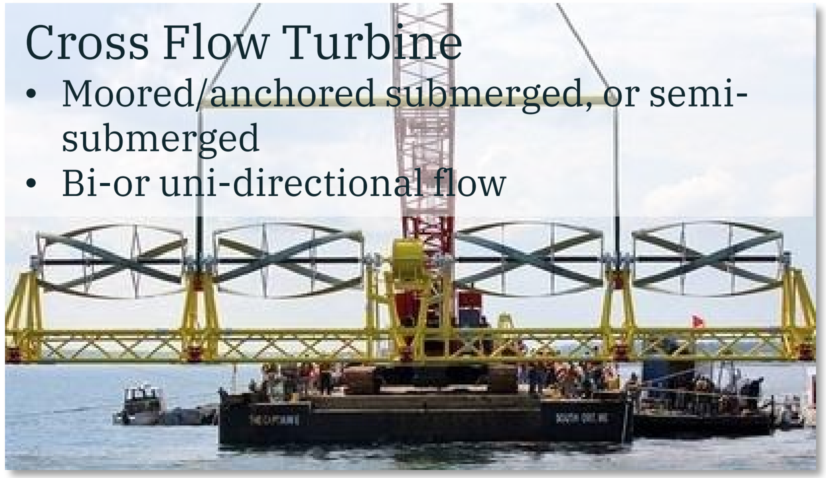
Tidal Energy Technology Overview - Refresher

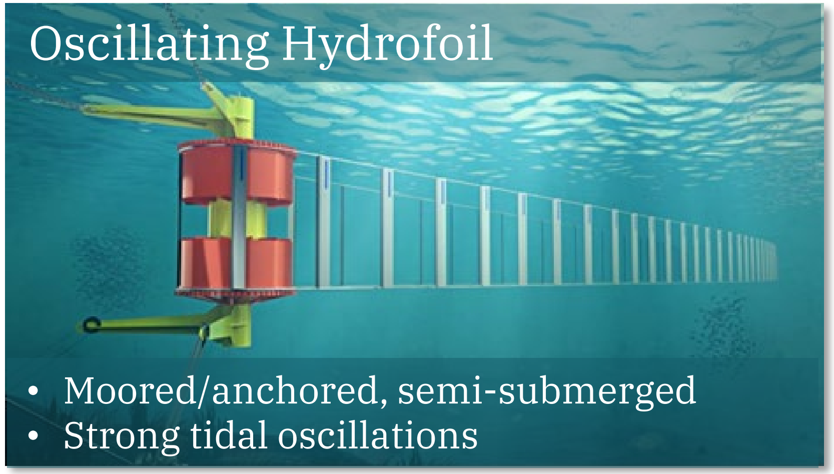
Axial Flow Turbine
- Bottom-mounted
- Bi- or uni-directional flow

SAE Renewables



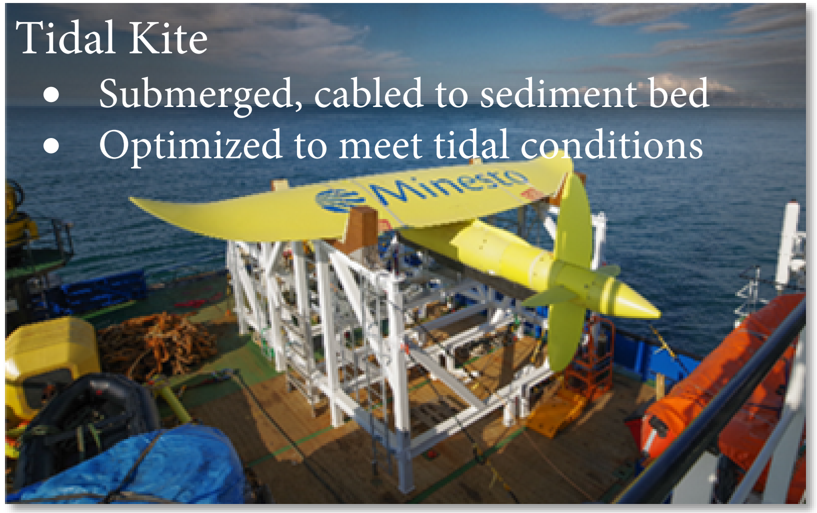
Cross Flow Turbine
- Moored/anchored submerged, or semi-submerged
- Bi-or uni-directional flow

Ocean Renewable Power Company



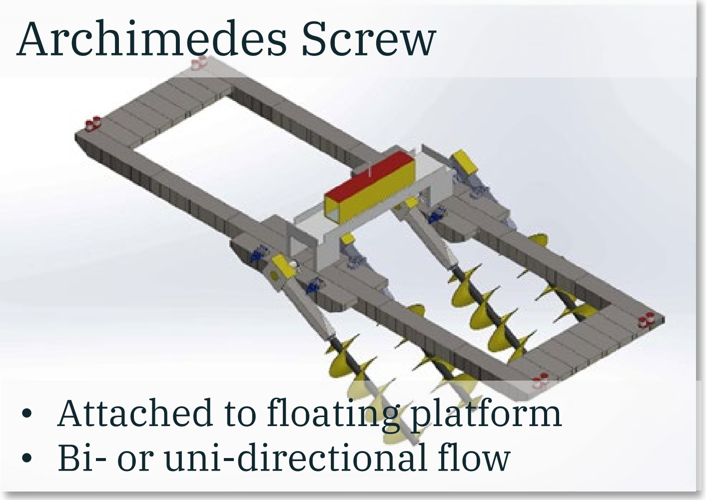
Oscillating Hydrofoil
- Moored/anchored, semi-submerged
- Strong tidal oscillations

Tidal Sails



Tidal Kite
- Submerged, cabled to sediment bed
- Optimized to meet tidal conditions

Minesto



Archimedes Screw
- Attached to floating platform
- Bi- or uni-directional flow

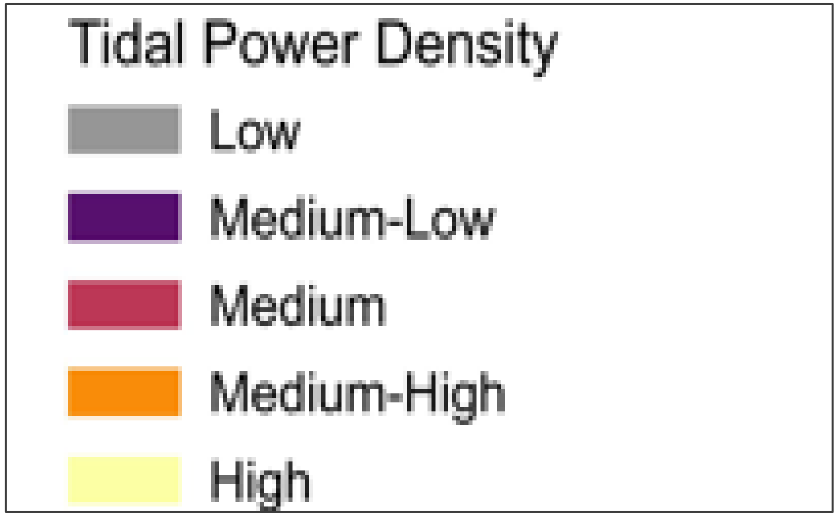
Jupiter Hydro

Vortex Induced Vibration
- Bottom mounted attached to generator

Vortex Hydro Energy

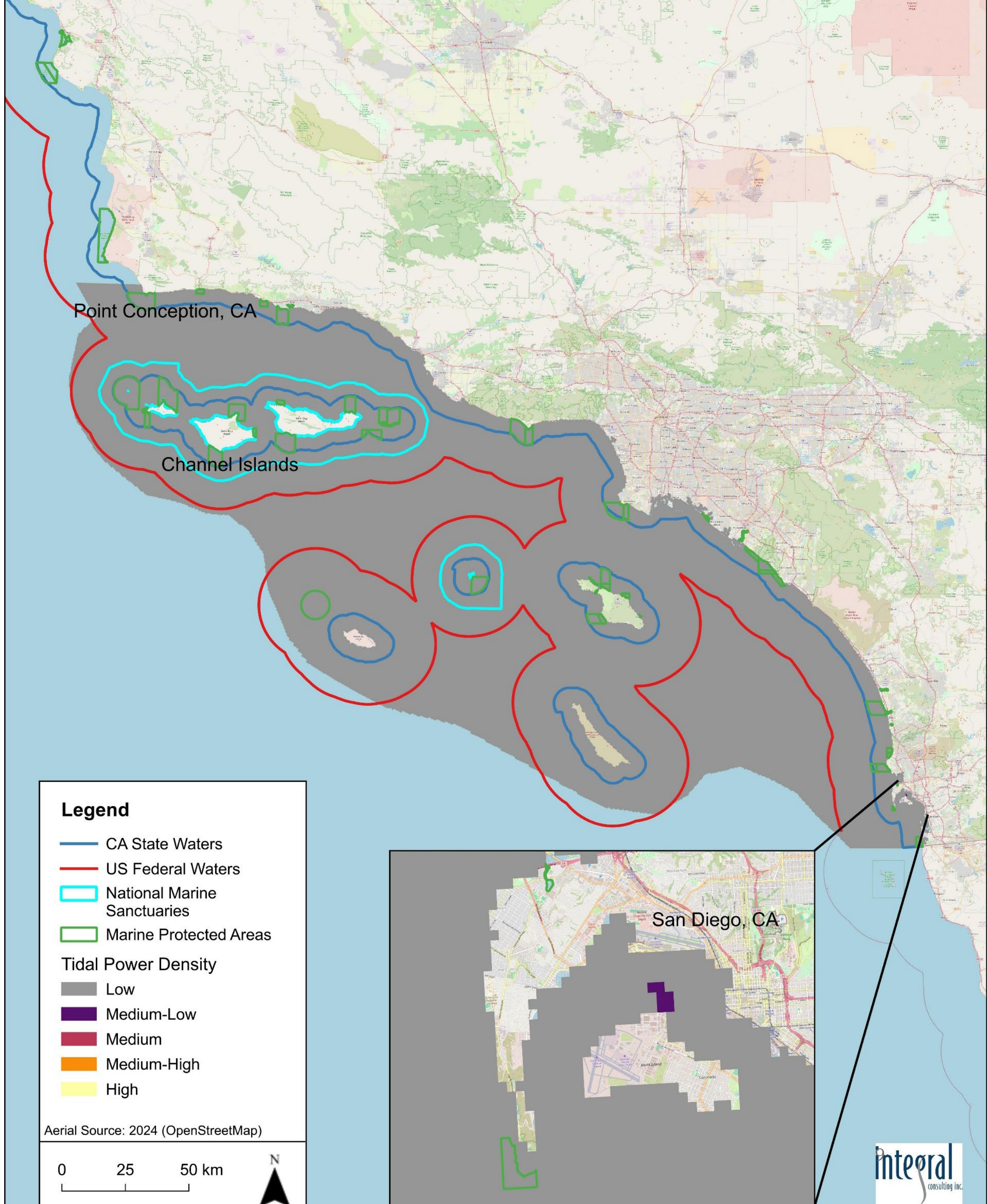
Tidal Energy Resource Data

- Average annual tidal power density from NREL (Haas et al. 2011)
  - Grids approximately 250m by 350m
- Results are reported in five categories/bins, in Watts per square meter:
  - Low Tidal Power Density: <200 W/m^2
  - Medium-Low: ≥200 to <400 W/ m^2
  - Medium: ≥400 to <600 W/ m^2
  - Medium-High: ≥600 to <800 W/ m^2
  - High Tidal Power Density: ≥800 W/ m^2

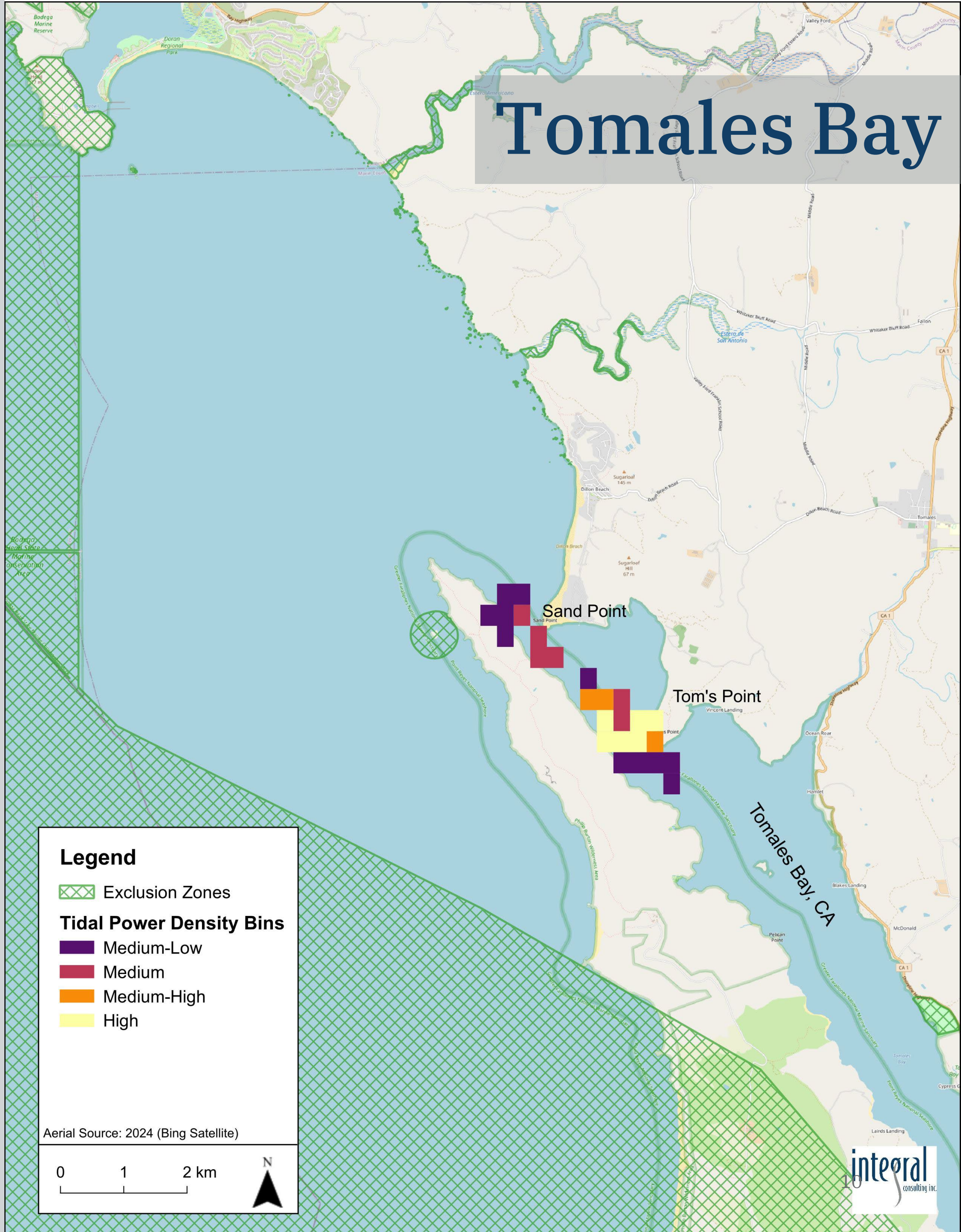


Southern California Tidal Energy Resources

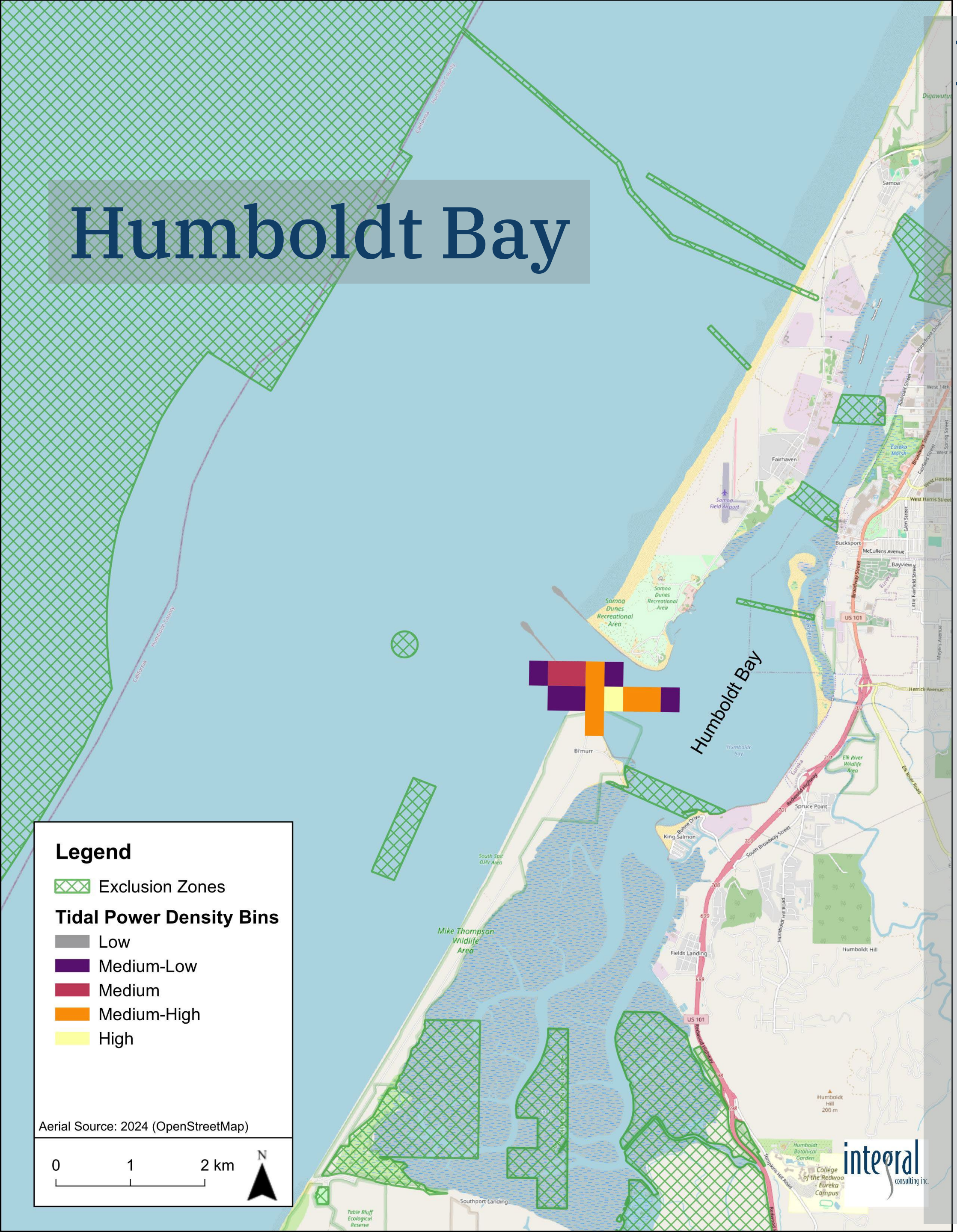
- Limited energy resources
- Small area of Medium- Low energy within San Diego Harbor
- Constraints with military, port, commuter ferry and recreational vessel traffic

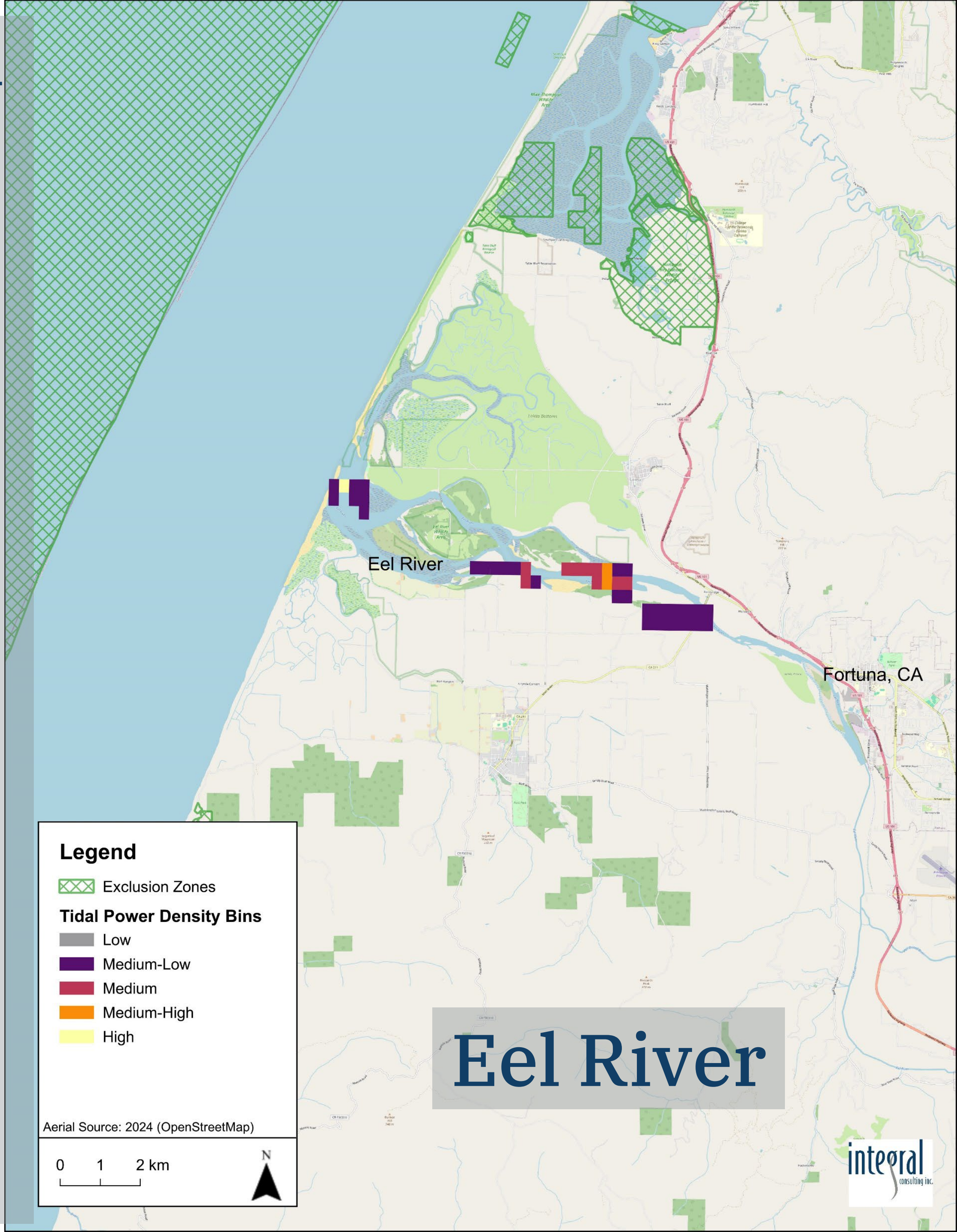


Central CA Tidal Energy

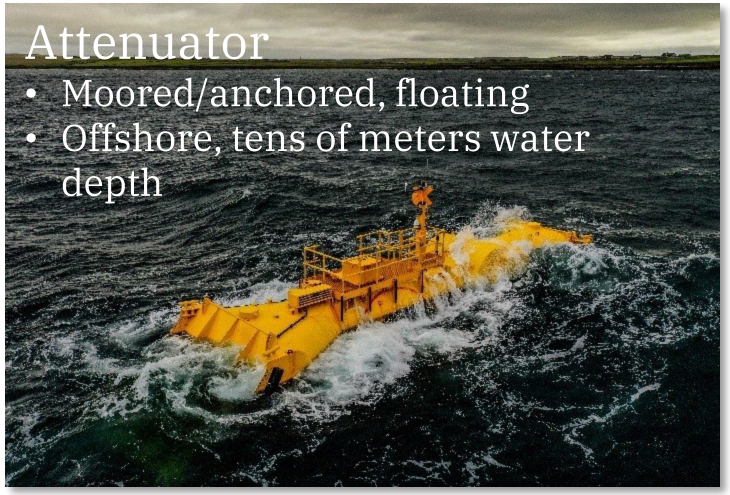


Northern CA Tidal Energy



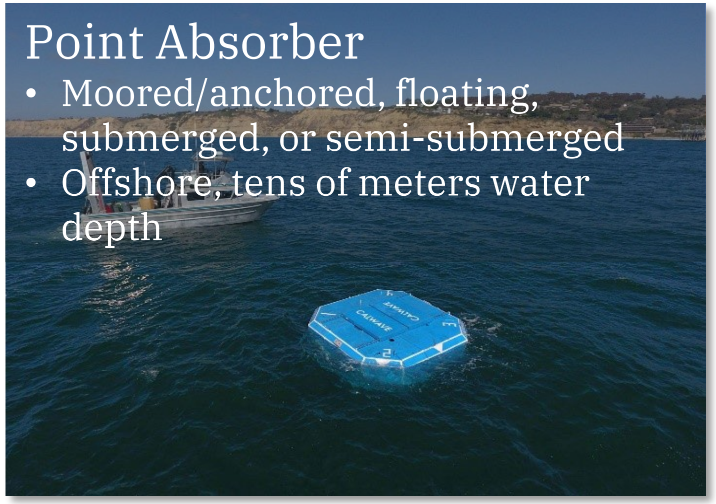


Wave Energy Technology Overview - Refresher



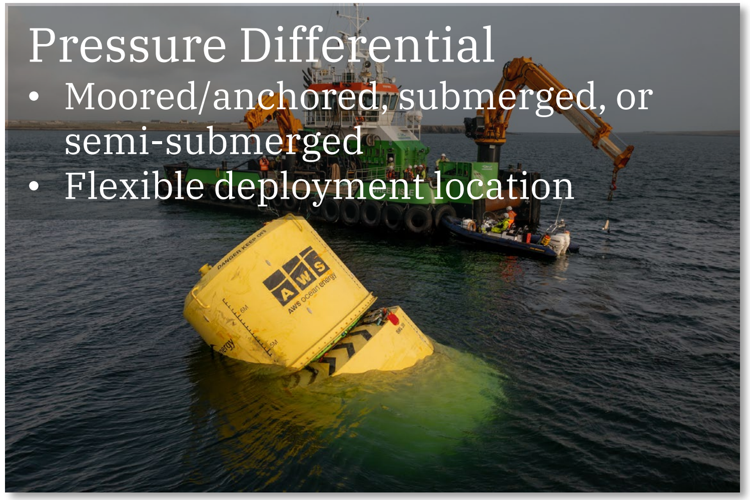
Attenuator
- Moored/anchored, floating
- Offshore, tens of meters water depth

Mocean Energy



Point Absorber
- Moored/anchored, floating, submerged, or semi-submerged
- Offshore, tens of meters water depth

CalWave



Pressure Differential
- Moored/anchored, submerged, or semi-submerged
- Flexible deployment location

AWS

Oscillating Water Column
- Fixed on land or seabed, or moored
- Shore-based, nearshore, or offshore

Ocean Energy

Overtopping
- Fixed on land or seabed or moored
- Shore-based, nearshore, or offshore

Wave Dragon

Oscillating Wave Surge
- Moored/anchored, floating, submerged, or semi-submerged, or bottom-fixed
- Nearshore, <12 water depth

Resolute Marine Energy

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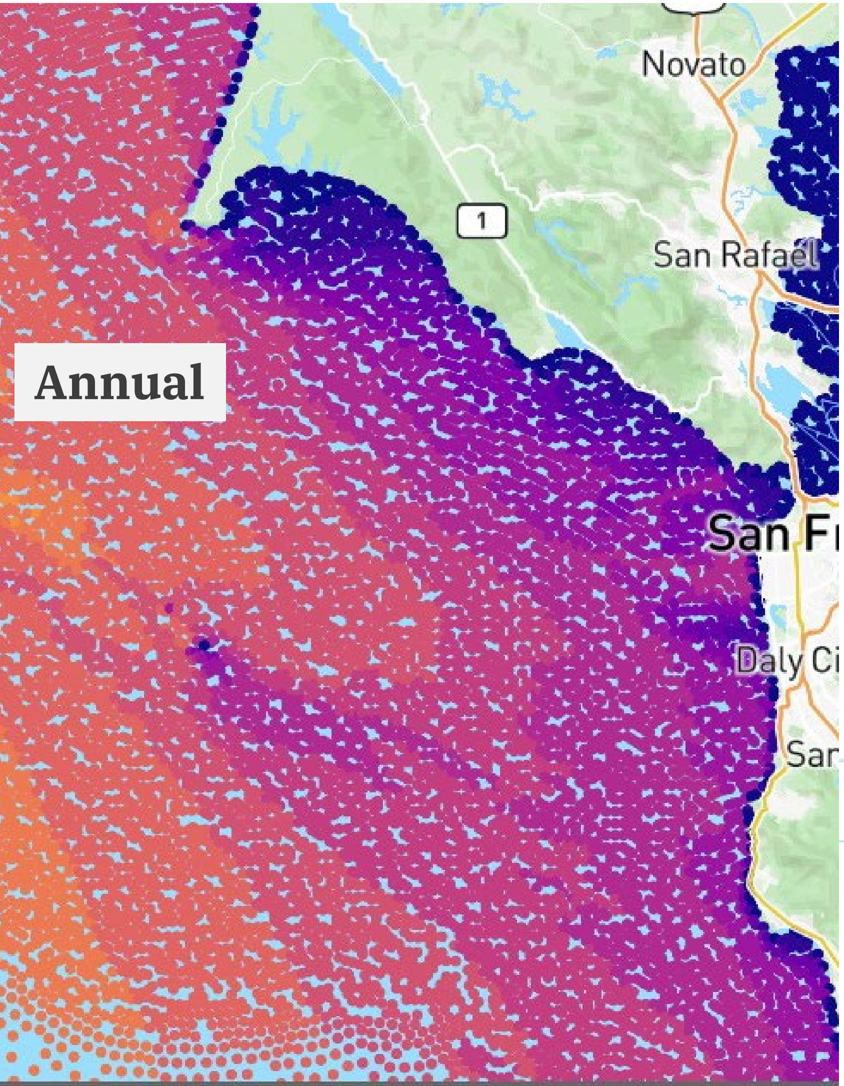
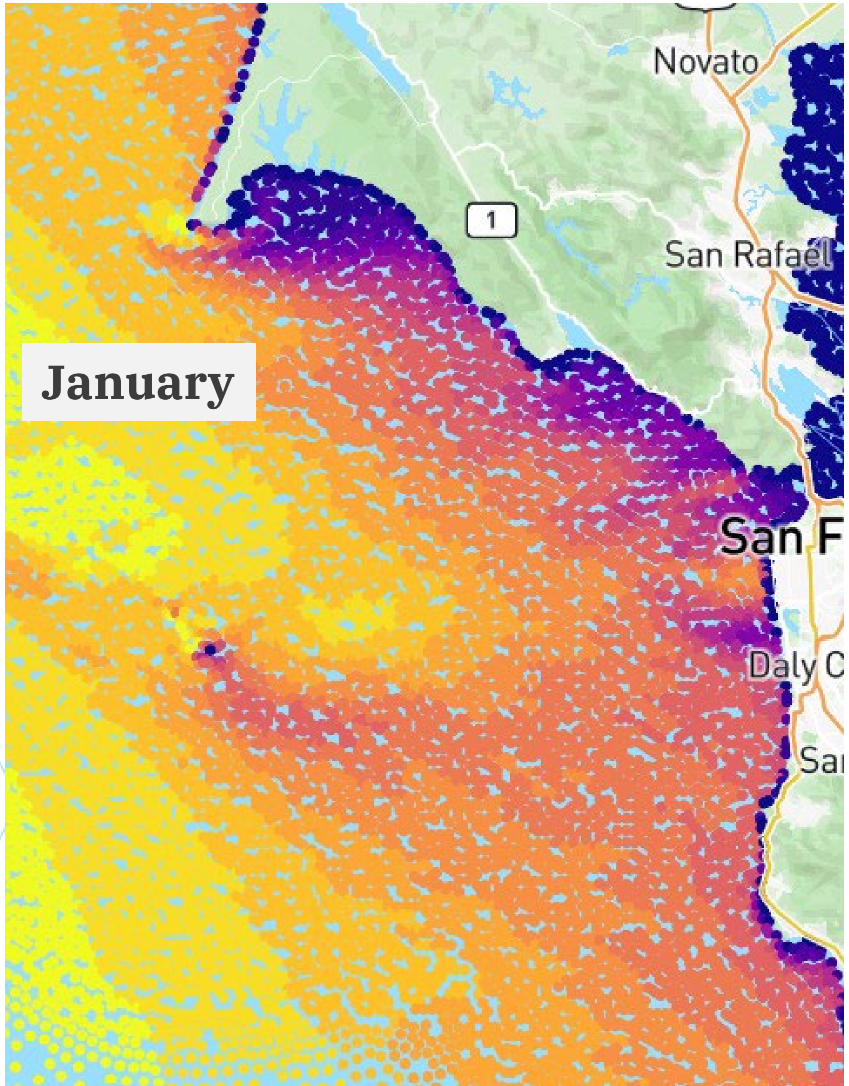
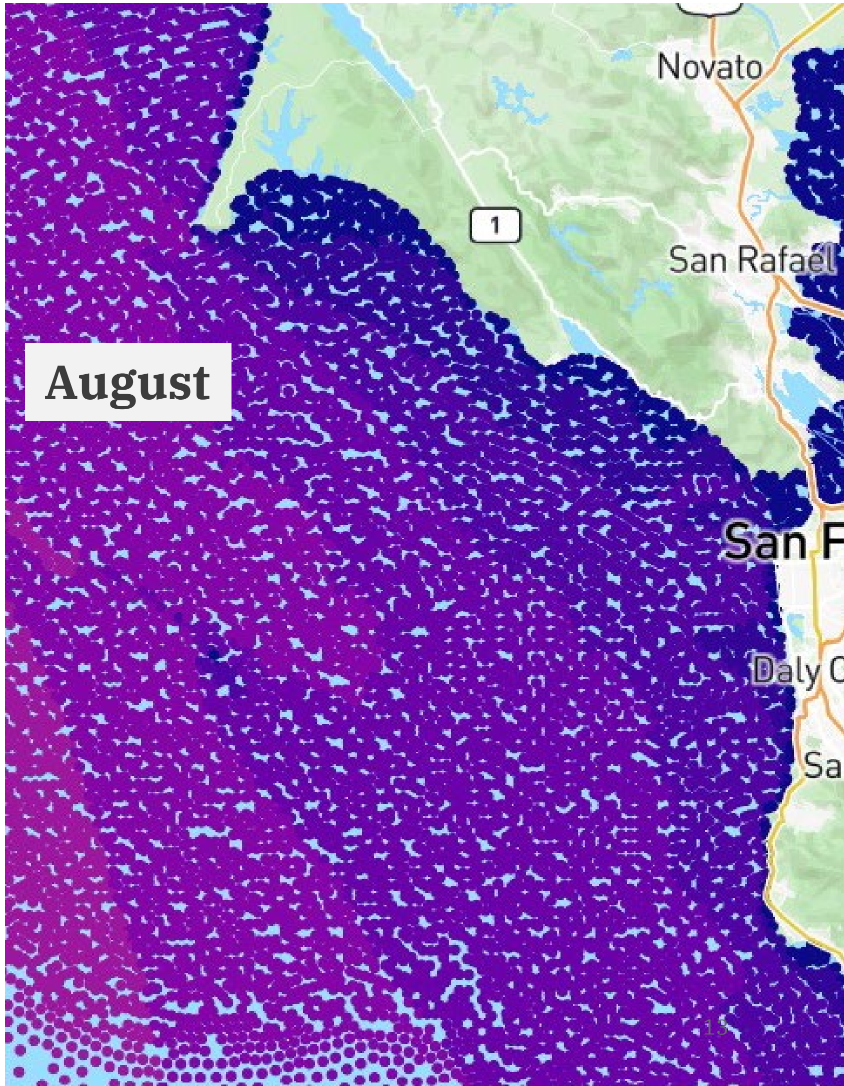
Wave Energy Resource Analysis

Average annual omnidirectional wave data from 2010 (most recent)







Wave Energy Data Summary

- Wave energy data is in point form, not gridded cells
- Energy classified into bands, in kilowatts per meter:
  - Low Omni-Directional Wave Power: < 10 kW/m
  - Medium-Low: ≥ 10 to < 20 kW/m
  - Medium: ≥ 20 to < 40 kW/m
  - Medium-High: ≥ 40 to < 50 kW/m
  - High Omni-Directional Wave Power: ≥ 50 kW/m

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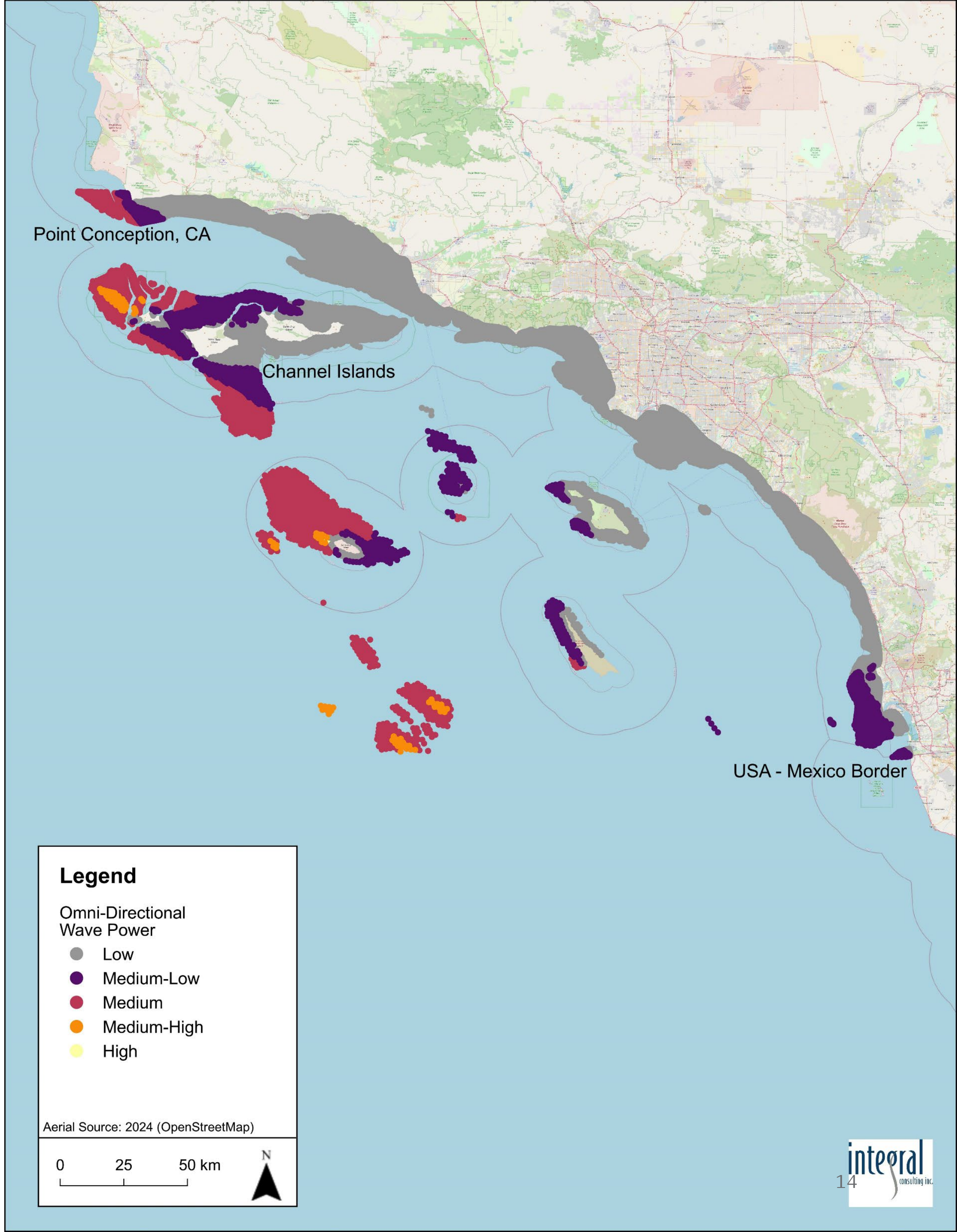

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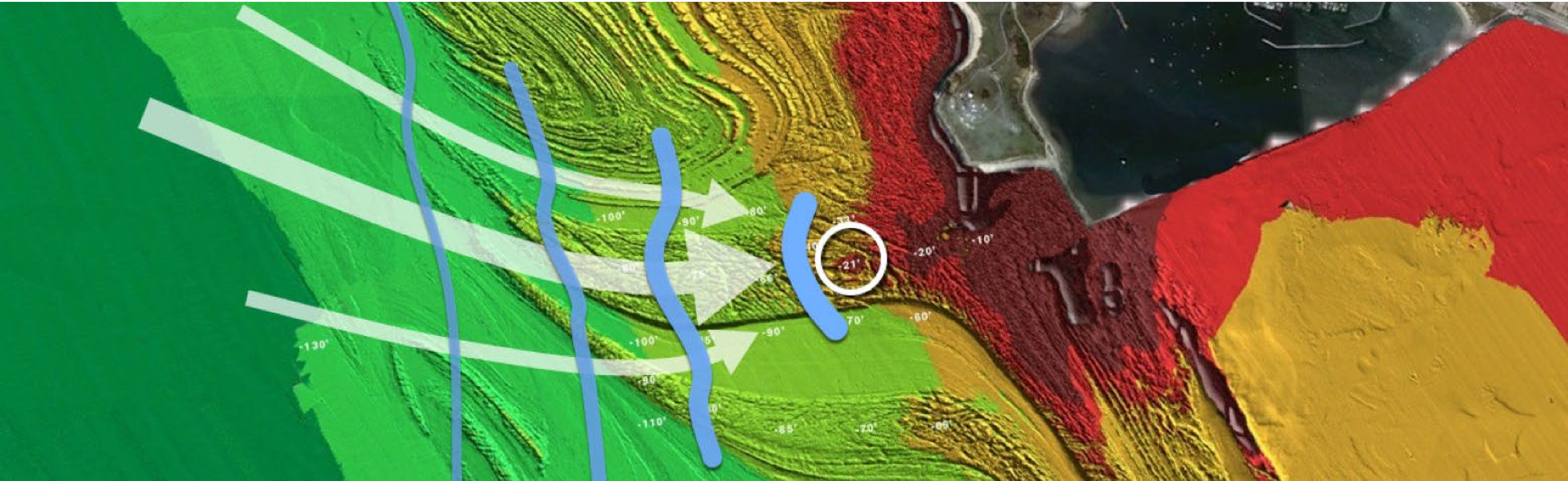
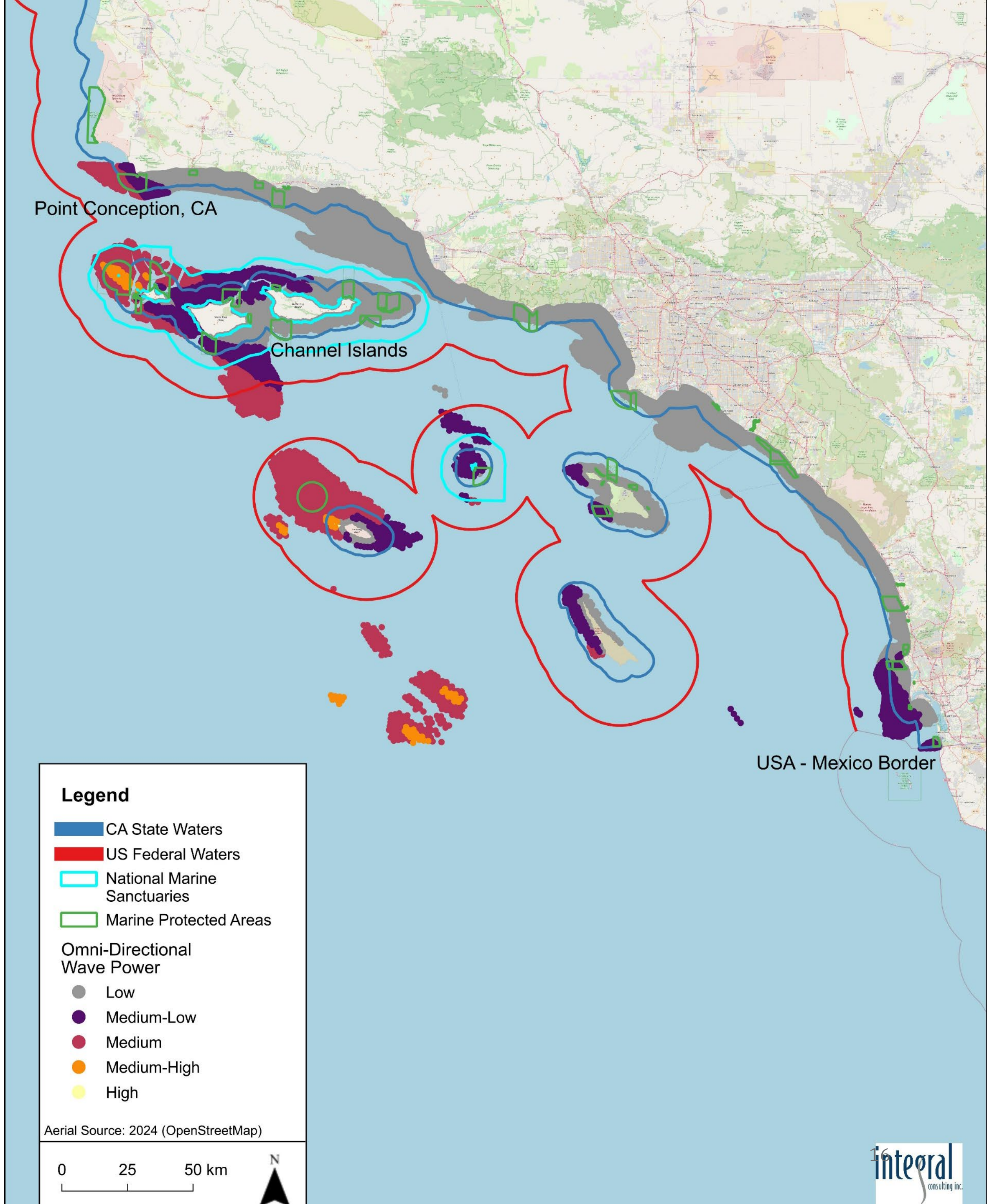
Wave Energy Resource Assessment Caveats

- Energy data in nearshore (<50 m water depth) is less reliable
  - Bathymetry and offshore structures or features become important
  - Projects require site- and device-specific wave modeling



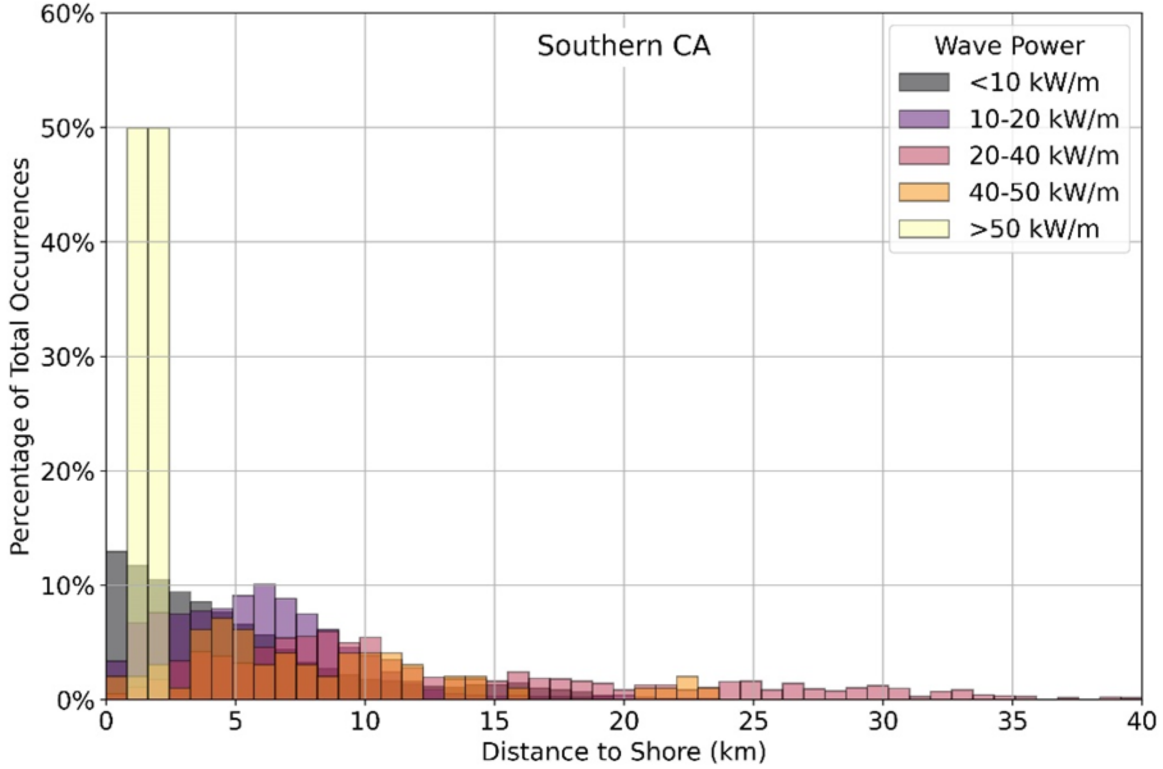
Southern California Wave Energy Resources

- Point Conception and Channel Islands block large swells from the northwest
- Greatest energy potential is around the Channel Islands
- Substantial overlap with marine protected areas, and areas used currently or in the past for defense activities



Southern California Wave Energy Constraints Analysis

- Areas of high energy close to shore
  - Channel Islands, not mainland – higher costs
- Highest energy areas entirely within areas with spatial constraints
- Medium-high resources are in water depths of 25-100 m



Power Bin	Point Count Total	Percent of Point Count in Unconstrained Zone
Low	31,884	22
Medium-Low	3,258	20
Medium	2,088	6
Medium-High	98	19
High	2	0

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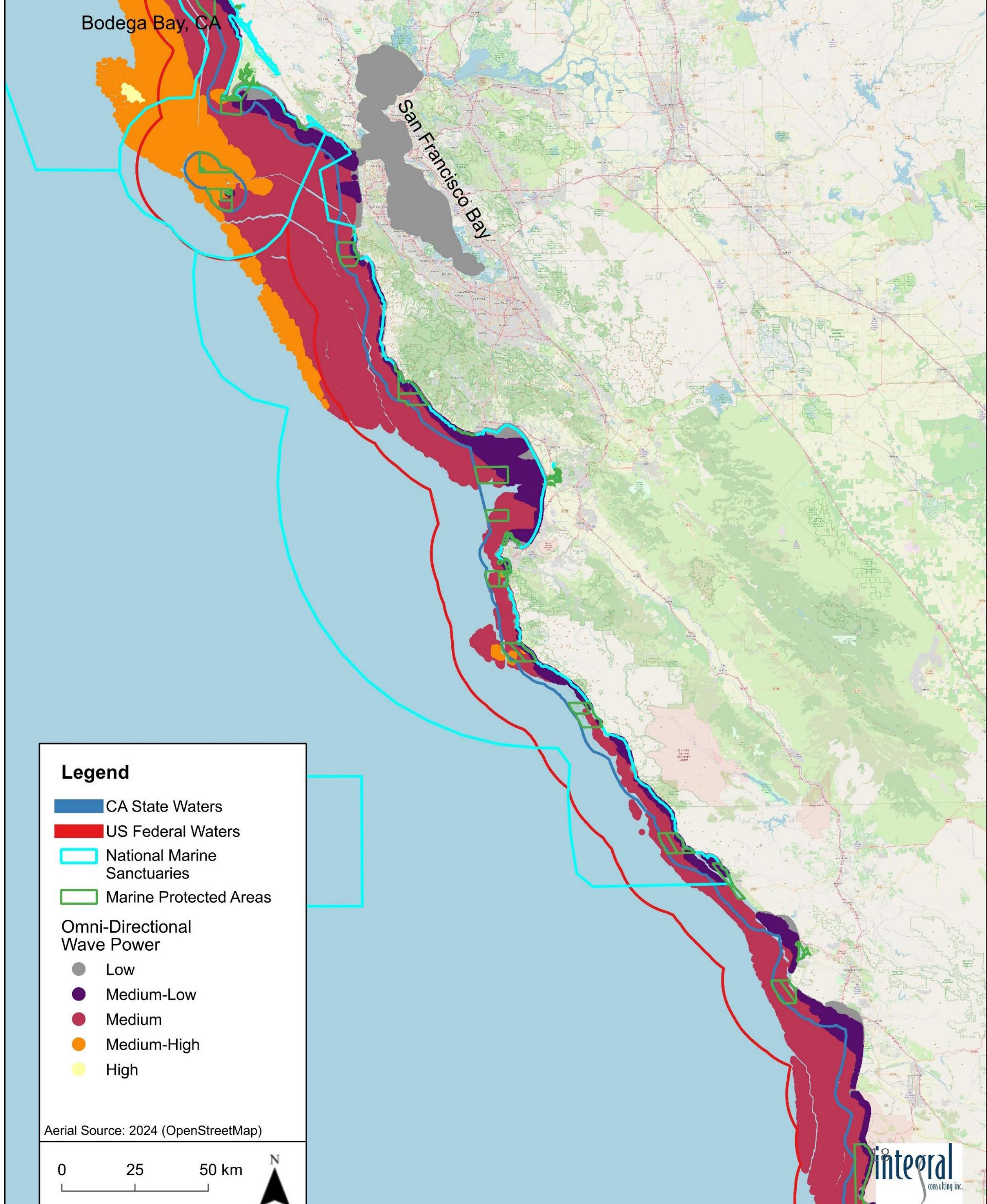
Central California Wave Energy Resources

› Energy resource is highest in the north of the region

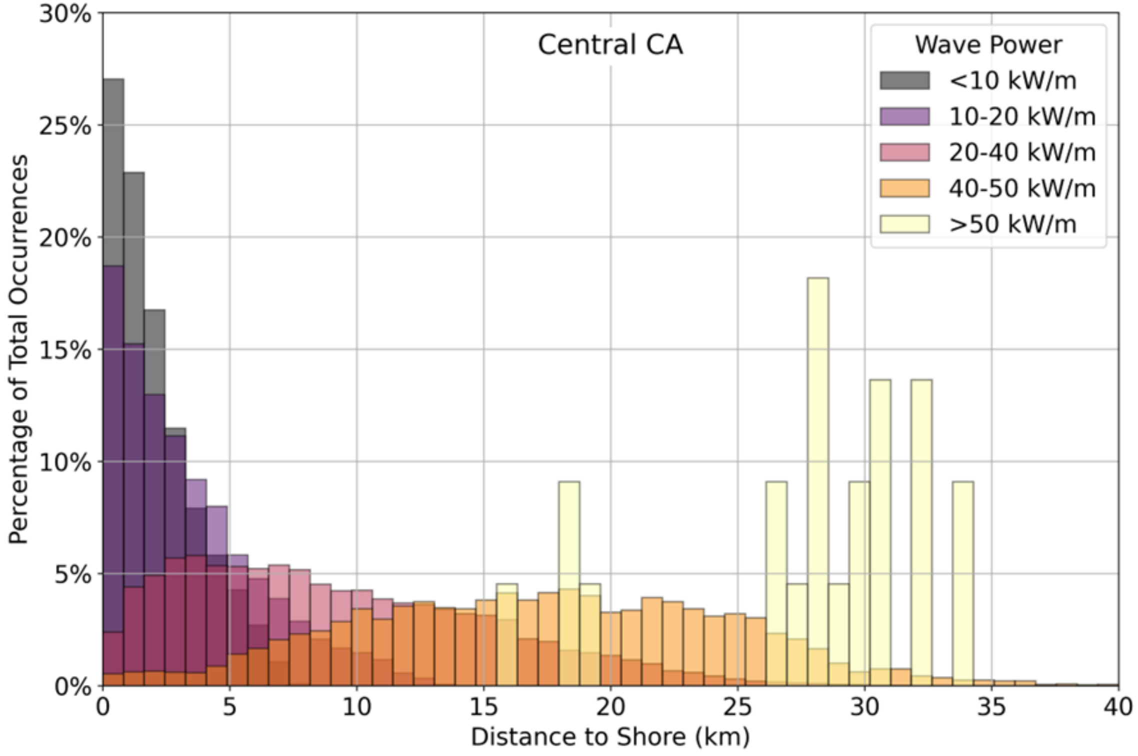
› Located relatively close to population center of San Francisco

› Highest energy resources located more than 15 km from shore

› Potential opportunities 5-15 km from shore with medium energy, fewer constraints



Central California Wave Energy Constraints Analysis

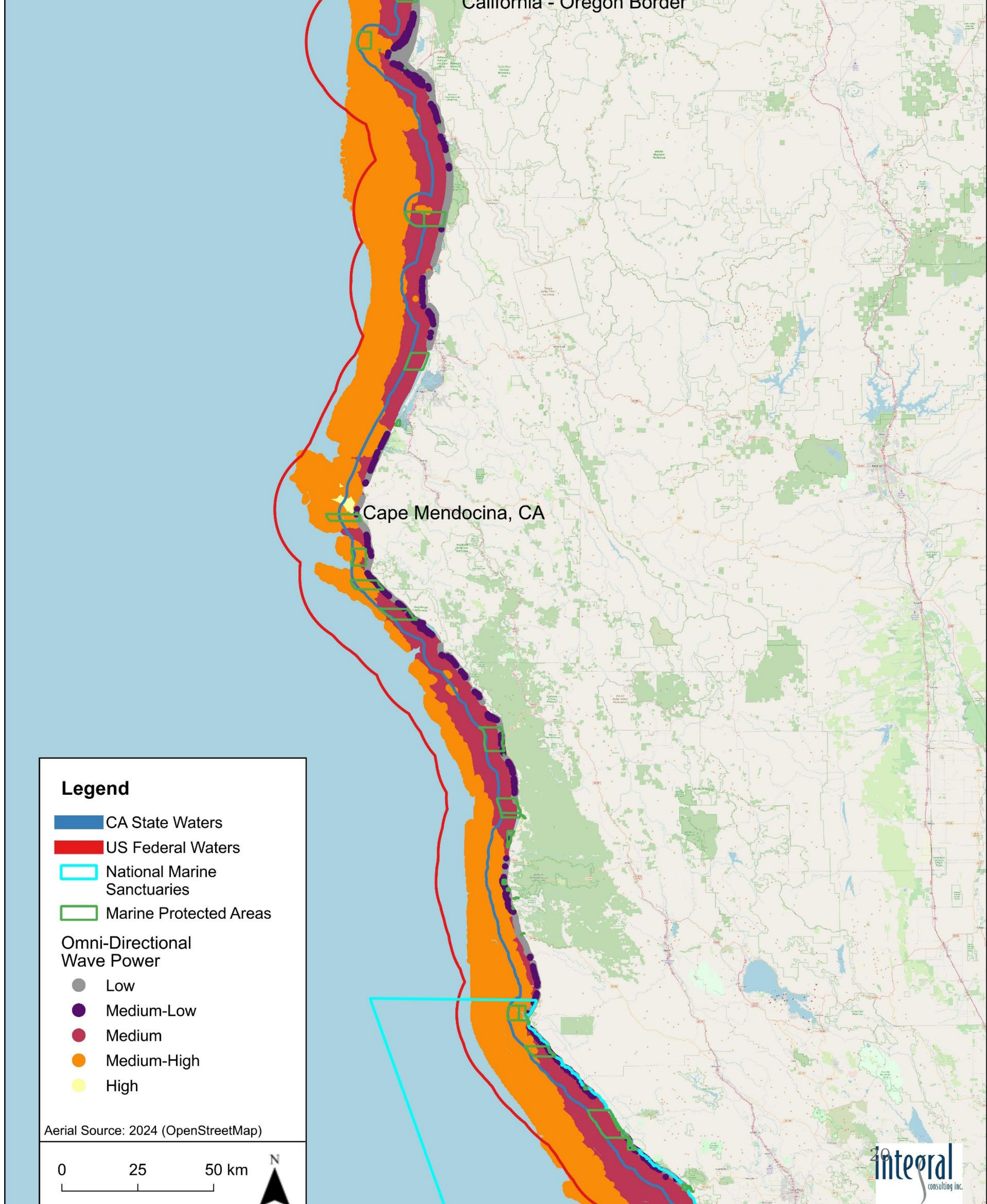


- Substantial overlap with oil and gas resource and planning areas
- More than 90% of wave energy in the highest two bins has spatial constraints

Power Bin	Point Count Total	Percent of Point Count in Unconstrained Zone
Low	20,002	68
Medium-Low	6,956	46
Medium	39,901	17
Medium-High	6,406	6
High	22	5

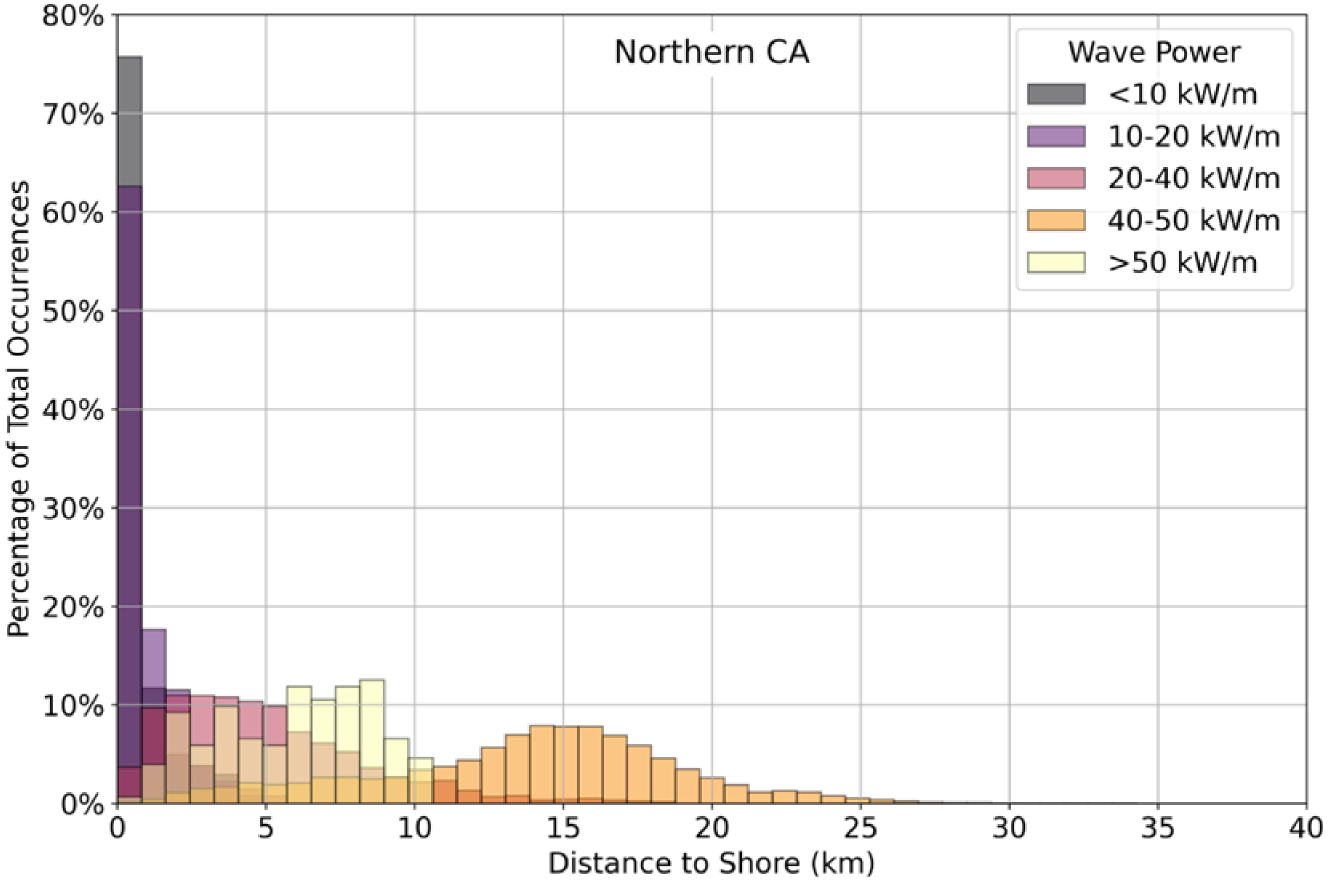
Northern California Wave Energy Resources

- Highest wave energy of the three regions
- Focusing due to underwater canyons
- Relatively even distribution of energy across the region



Northern California Wave Energy Constraints Analysis

- Highest energy is within 10 km of shore
- In some locations, high energy resource is located less than 5 km from shore
  - Importance of canyons
- Fewer constraints than in other regions



Power Bin	Point Count Total	Percent of Point Count in Unconstrained Zone
Low	1,638	83
Medium-Low	679	72
Medium	19,478	46
Medium-High	22,641	7
High	152	84

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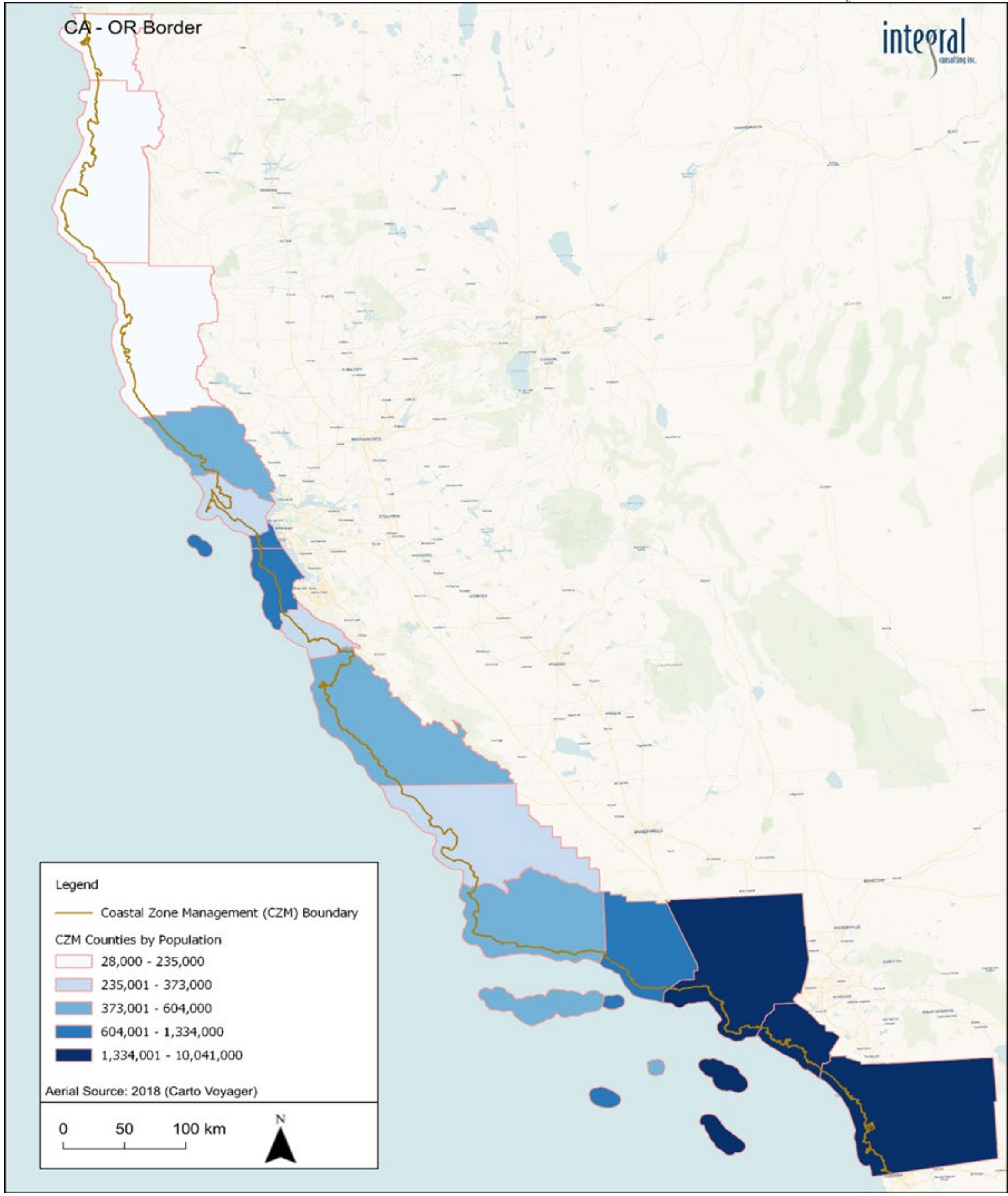
Chapter 2 – Marine Energy Project Considerations

- Technologies and Site Selection
  - Device suitability
  - Site selection
  - Summary of supporting and limiting factors in each region
- Potential Opportunities and Applications
  - Commercial Scale Opportunities
  - Near term distributed opportunities
- Previous Marine Energy Projects in California

Alignment of Demand and Supply

- Population of California is highly coastal
- Higher density in Southern California
- To align with renewable energy targets, will need to replace existing fossil fuel power plants
  - 20% in Central California
  - 78% in Southern California

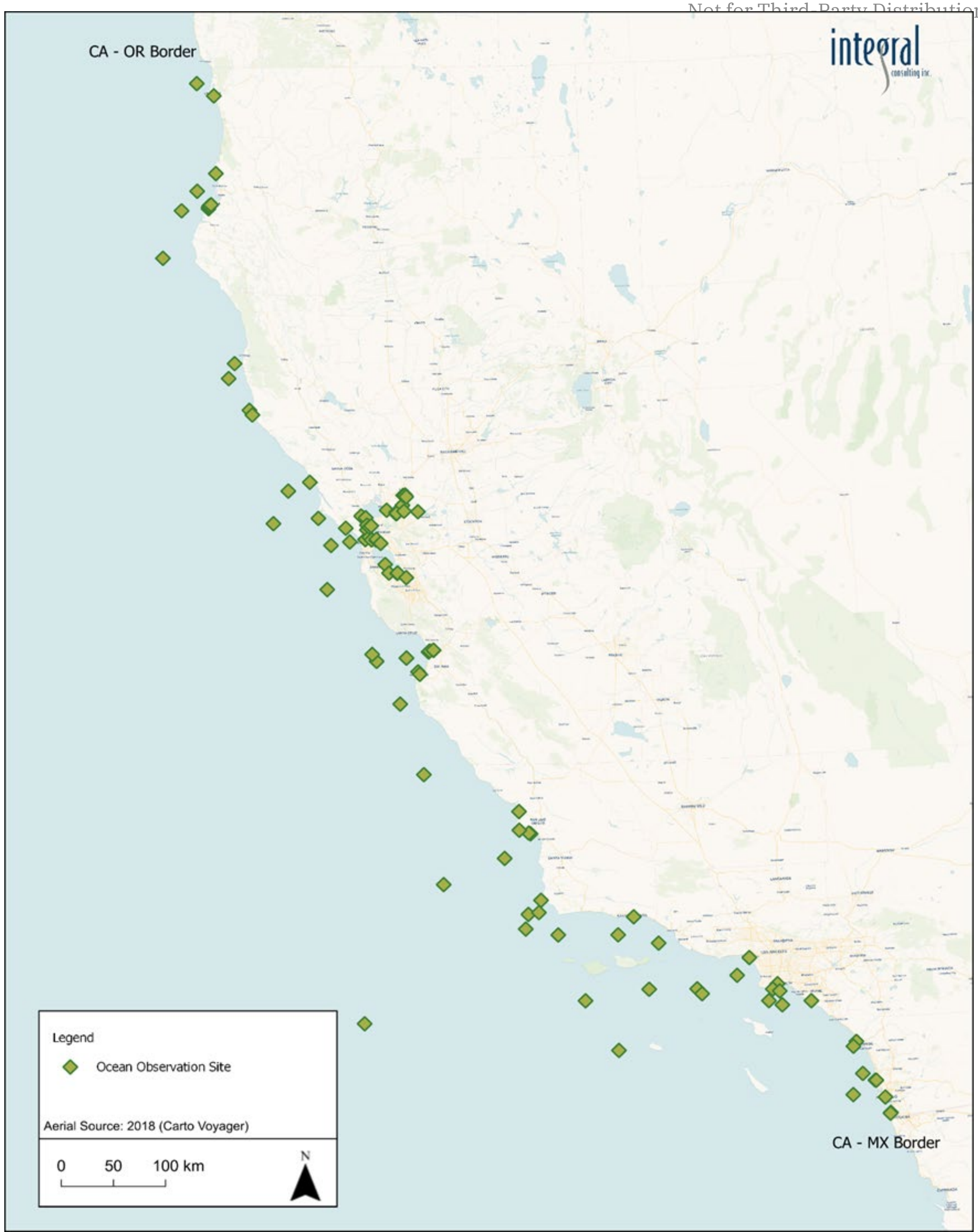


Port Infrastructure

- Powering port activities
- Fishing infrastructure and processing
- Integrated with existing coastal structures

Other Opportunities

- Aquaculture
  - Protecting offshore pens/cages
  - Powering operational needs
- Desalination
- Ocean observation buoys
  - Environmental
  - Metocean



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Previous Marine Energy Projects

- Prior to 2015, failures and bankruptcies
  - Failures in cost estimation
  - Non-compliance with permit or financial requirements
  - Due-diligence failures
- Since 2020, some successes and permitting advances
  - CalWave completed 10-month field trial off Scripps Pier
  - Eco Wave Power permitted for installation at Port of Los Angeles

Marine Energy Opportunities Summary

- Tidal energy resource is limited, with San Francisco the most viable
- Wave energy is greatest in the north of the state, away from major population centers
  - New transmission infrastructure will be necessary if grid connection is the objective
  - In the near-term, distributed opportunities are more promising
- Local, device-specific modeling is required, particularly for nearshore applications
- All projects will require environmental permits and additional analysis

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