APPENDIX A

List of Authors

REGIONAL ENVIRONMENTAL ASSESSMENT – SCOPING REPORT

List of Authors

The following people have been proposed as authors of the Regional Environmental Assessment. Wherever possible, expertise has been sought from within Guernsey. Where insufficient expertise exists, or specialists have been found not to be available to work on the project, the search has extended to the other Channel Islands or to the UK.

Table B.01 Authors

Subject / Role	Author	Organisation
Geology, Bathymetry and Sediment Transition	David Tappin	British Geological Survey
Marine Processes	Chris Green	GREC
Sediment Contamination and Water Quality	Peter Barnes	States of Guernsey
Protected Sites and Species	Charles David	Guernsey Biological Records Centre
Benthic Ecology	Melanie Broadhurst Emma Sheehan Nova Mieszkowska	Imperial College, London PRIMaRE Marine Biological Association
Pelagic Ecology	Annie Linley	Plymouth Marine Labs
Birds	Jamie Hooper	Environment Guernsey
Marine Mammals	Martin Gavet	States of Guernsey
Commercial Fisheries	David Wilkinson	Fisheries, States of Guernsey
Recreational Fishing	Peter Perrio	States of Guernsey
Marine and Coastal Historic Environment	Philip de Jersey Tanya Walls	Archaeology Officer, States of Guernsey Archaeology Assistant, States of Guernsey
Cables Pipelines and Onshore Grid Connections	Steve Morris	Guernsey Electricity
Shipping and Navigation	Robert Barton	Former Harbourmaster, States of Guernsey
Tourism and Recreation	Chris Elliot Jan Dockerill	Director of Tourism, States of Guernsey Environment Department, States of Guernsey
Ambient Noise	Peter Barnes	States of Guernsey
Air Quality	Peter Barnes	States of Guernsey
Electro-magnetic Fields	Steve Morris	Guernsey Electricity
Landscape and Seascape Character	Faith Rose	States of Guernsey
Social Aspects	Chris Green	GREC
Internal Review	Andrew Casebow	States of Guernsey
	Nick Day	GREC
	Scientific Committee	La Société Guernesiaise
Possible External Peer Reviewers (To be confirmed)	Philip Leeks	SEPA
	Alexander Downey	SEPA
	Nicky Chapman	JNCC
	Keith Welford	DECC
	Peter Hughes	Halcrow
		BWEA

APPENDIX B

Glossary of Terms

REGIONAL ENVIRONMENTAL ASSESSMENT – SCOPING REPORT

Glossary of Terms

ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
EMF	Electro-magnetic Field
EAP	Environmental Action Plan
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EPS	European Protected Species
ES	Environmental Statement
GEL	Guernsey Electricity Ltd
EU	European Union
FEPA	Food and Environment Protection Act
GIS	Geographical Information System
GREC	Guernsey Renewable Energy Commission
GREF	Guernsey Renewable Energy Forum
GW	GigaWatt
GWh	GigaWatt Hour
RAMSAR	Inter-governmental convention on wetlands, signed in Ramsar, Iran, in 1971. Often used to refer to a designated site enjoying environmental protection
JNCC	Joint Nature Conservation Committee
MSP	Marine Spatial Plan
MW	MegaWatt
OUR	Office of Utility Regulation

O&M	Operation and Maintenance
REA	Regional Environmental Assessment
SEA	Strategic Environmental Assessment

APPENDIX C

Wave and Tidal Devices in Development

Appendix C

Wave and Tidal Devices in Development

The following tables outline companies and their devices that are currently under various stages of development around the world. The basis for these tables is information taken from the EMEC website - http://www.emec.org.uk/index.asp .

Summary of Wave Devices

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Able Technologies L.L.C.	*Electric Generating Wave Pipe*	Point Absorber	http://www.abletechnologiesllc.com	Concept	USA
Applied Technologies Company Ltd	*Float Wave Electric Power Station*	Point Absorber	http://www.atecom.ru/wave-energy/	Small Scale Laboratory testing.	Russia
Aqua Energy / Finevara Renewables	*Aqua Buoy*	Point Absorber	http://finavera.com/	Field Test at Makah Bay, Washington and Figueira da Foz, Portugal	USA
Aquamarine Power	*Oyster*	*Oscillating Wave Surge Converter*	http://www.aquamarinepower.com/	Currently undergoing full Scale Testing at EMEC's testing site of Orkney	UK
Atmocean	*Atmocean*	Point Absorber	http://www.atmocean.com/	Conducted 21 ocean tests of various depths and sizes.	USA
AW Energy	*Waveroller*	*Oscillating Wave Surge Converter*	http://www.aw-energy.com/	Device installed off Portugal	Finland
AWS Ocean Energy	*Archimedes Wave Swing*	*Submerged Pressure Differential*	http://www.awsocean.com/PageProducer.aspx	Testing at EMEC	UK
Balkee Tide and Wave Electricity Generator	*TWPEG*	Point Absorber	N/A	Unknown	Mautitius
BioPower Systems Pty Ltd	*bioWave*	*Oscillating Wave Surge Converter*	http://www.biopowersystems.com/	250kW Pilot project at King Island, Tasmania is being developed for deployment 2010.	Australia
Bourne Energy	*OceanStar ocean power system*	*Wave Rotor*	http://www.bourneenergy.com/future.html	Concept	USA

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Brandl Motor	*Brandl Generator*	Point Absorber	http://brandlmotor.de/index_eng.htm	Small scale model in North Sea	Germany
Checkmate Seaenergy UK Ltd.	*Anaconda*	OTHER / Attenuator	http://www.checkmateuk.com/seaenergy/	Laboratory tested	UK
Columbia Power Technologies	*Direct Drive Permanent Magnet Linear Generator Buoy*	Point Absorber	http://www.columbiapwr.com/#	10 kW buoy deployed 2.5 miles off Newport, Oregon for 5 days	USA
C-Wave	*C-wave*	*Attenuator*	http://www.cwavepower.com/	Concept	UK
Daedalus Informatics Ltd	*Wave Energy Conversion Activator*	*Oscillating Water Current*	http://www.daedalus.gr/	Concept	Greece
DEXA Wave UK Ltd	*DEXA Wave Energy Converter*	*Attenuator*	http://www.dexawaveenergy.co.uk/	Concept	USA
Ecofys	*Wave Rotor*	*Wave Rotor*	http://www.ecofys.com/com/news/pressreleases2002/pressrelease02aug2002.htm	1:10 scale tests on the north-west coast of Denmark	Netherlands
Ecole Centrale de Nantes	*SEAREV*	Point Absorber	http://www.ec-nantes.fr/	Concept	France
Edinburgh University	*Sloped IBS Buoy*	*Attenuator*	http://www.mech.ed.ac.uk/research/wavepower/sloped%20IPS/Sloped%20IPS%20intro.htm	Concept	UK
ELGEN Wave	*Horizon Platform*	Point Absorber	http://www.elgenwave.com/	Tested three models	USA
Embley Energy	*Sperboy*	*Oscillating Water Column*	http://www.sperboy.com/	1/5 scale testing in 1999-2001	UK
Energias de Portugal	*Foz do Douro breakwater*	*Oscillating Water Column*	N/A	Field test at Foz do Douro, Portugal	Portugal
Euro wave energy	*Floating absorber*	Point Absorber	http://www.eurowaveenergy.com/ewe/public/openIndex?ARTICLE_ID=100	Concept	Norway
Float Inc.	*Pneumatically Stabilized Platform*	Point Absorber / Attenuator / Oscillating Water Column	http://www.floatinc.com/	Undisclosed	USA
Floating Power Plant ApS (F.P.P.)	*Poseidon's Organ*	*Oscillating Wave Surge Converter*	http://www.poseidonorgan.com/	Reduced-scale prototype at Lolland, Denmark	Denmark

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Fobox AS	*FO3*	Point Absorber	N/A	Unknown	Norway
Fred Olsen & Co./Ghent University	*SEEWEC*	Point Absorber	http://www02.abb.com/global/gad/gad02077.nsf/lupLongContent/D74F5739AAE738F6C12571D800305007	1:20 and 1:3 scale models tested.	Norway / EU
Green Ocean Energy Ltd	*Ocean Treader WEC*	*Attenuator / point absorber*	http://www.greenoceanenergy.com/	Prototype planned for 2011	UK
Green Ocean Energy Ltd	*WaveTreader WEC*	*Attenuator / point absorber*	http://www.greenoceanenergy.com/index.php/wave-treader	Prototype planned for 2009, commercially ready planned 2011	UK
Greencat Renewables	*Wave Turbine*	*Submerged Pressure Differential*	http://www.greencatrenewables.co.uk/	Concept	UK
GyroWaveGen	*GyroWaveGen*	OTHER	N/A	Unknown	USA
Hydam Technology	*McCabe Wave Pump*	*Attenuator*	N/A	Unknown	Ireland
Hidroflot s.l.	*Multi cell platforms*	Point Absorber	http://www.hidroflot.com/	Concept	Spain
Independent Natural Resources	*SEADOG*	Point Absorber	http://www.inri.us/	Pilot-scale field tests near Freeport and Galveston, Texas	USA
Indian Wave Energy Device	*IWAVE*	Point Absorber	http://waveenergy.nualgi.com/	Patented concept	India
Ing Arvid Nesheim	*Oscillating Device*	Point Absorber	http://www.anwsite.com/	Concept	Norway
Instituto Superior Tecnico	*Pico OWC*	*Oscillating Water Column*	http://www.pico-owc.net/	Field tests in Pico Island, Azores, Portugal	Portugal
Interproject Service (IPS) AB	*IPS OWEC Buoy*	Point Absorber	http://www.ips-ab.com/	Field tested and ready for commercial deployment	Sweden
JAMSTEC	*Mighty Whale*	*Oscillating Water Column*	http://www.jamstec.go.jp/jamstec/MTD/Whale/	Field tested in Gokasho Bay, Japan	Japan
Jospa Ltd	*Irish Tube Compressor (ITC)*	*Overtopping Device*	http://www.jospa.ie/	Concept	Ireland

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Joules Energy Efficiency Services Ltd	*TETRON*	Point Absorber / OTHER	N/A	Prototype tested in 2005-06	Ireland
Lancaster University	*PS Frog*	Point Absorber	http://www.engineering.lancs.ac.uk/lureg/research/wave%20energy.asp	Concept	England
Langlee Wave Power	*Langlee System*	*Oscillating Wave Surge Converter*	http://www.langlee.no/	Pilot testing planned off Turkish coast 2010 – then full scale 24 MW commercial farm	Norway
Leancon Wave Energy	*Multi Absorbing Wave Energy Converter (MAWEC)*	*Oscillating Water Column*	http://www.leancon.com/technology.htm	1:40 scale test model in wave tank in 2005	Denmark
Manchester Bobber	*Manchester Bobber*	Point Absorber	http://www.manchesterbobber.com/index.htm	Technology is planned and ready for build – to be tested at EMEC	UK
Martifer Energia	*ONDA 1*	Attenuator	http://www.martifer.com/Group/EN/home.html	Unknown	Portugal
Motor Wave	*Motor Wave*	Point Absorber	http://www.motorwavegroup.com/new/index1.html	Tested in China	Hong Kong
Muroran Institute of Technology	*Pendulor*	*Oscillating Wave Surge Converter*	http://www.muroran-it.ac.jp/index-e.html	Tested in Matshike Harbor, Muroran, Japan	Japan
Nautilus	*Wave Energy Convertor for near shore deployment. Buoy driven piston driving pressurised air to onshore energy convertor*	Point Absorber	http://nautiluswaveenergy.com/	Concept and small scale proof of concept	Israel
Neptune Renewable Energy Ltd	*Triton*	*Oscillating Wave Surge Converter*	http://www.neptunerenewableenergy.com/	Concept	UK
Neptune Systems	*MHD Neptune*	Point Abosorber	N/A	Unknown	Netherlands
Norwegian University of Science and Technology	*CONWEC*	Point Absorber	http://www.sffe.no/energi/hav/bolge_e.htm	Unknown	Norway
Ocean Energy Ltd	*Ocean Energy Buoy*	*Oscillating Water Column*	http://www.oceanenergy.ie/	Tested in Galway, Ireland	Ireland

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Ocean Motion International	*OMI Combined Energy System*	Point Absorber	http://www.oceanmotion.ws/	1:20 scale model	USA
Ocean Navitas	*Aegir Dynamo*	Point Absorber	http://www.oceannavitas.com/	Plans to deploy in Wave Hub project off Cornwall and at the EMEC site in the Orkneys	UK
Ocean Power Technologies	*Power Buoy*	Point Absorber	http://www.oceanpowertechnologies.com/index.htm	Tested Atlantic City - New Jersey, Oahu – Hawaii, Santona - Spain Planned for Wave Hub in Cornwall and at EMEC in the Orkneys	UK / USA
Ocean Wave Energy Company	*OWEC*	*Submerged Pressure Differential*	http://www.owec.com/	Concept	USA
Ocean Wavemaster Ltd	*Wave Master*	Point Absorber	N/A	Unknown	UK
Oceanlinx (formerly Energetech)	*Denniss-Auld Turbine*	*Oscillating Water Column*	http://www.oceanlinx.com/	Full scale Prototype, 1/3 scale prototype tested in Port Kembla – Australia. Planned for Pre-commercial test planned for Wave Hub Cornwall	Australia
Oceantec Energías Marinas, S.L.	*Oceantech Energy Convertor*	*Attenuator*	N/A PDF at - http://www.eve.es/jornadas/ponencias_energia_marina_09/Presentacion%20OCEANTEC_02042009.pdf	Sea Trials of ¼ scale prototype in 2008 and 2009. Plans for full scale prototype in 2011	Spain
Offshore Islands Limited	*Wave Catcher*	OTHER	http://www.offshoreislandslimited.com/	Concept	USA
Offshore Wave Energy Ltd	*OWEL Energy Converter*	*Oscillating Water Column*	http://www.owel.co.uk/print/overview.htm	1:10 scale model tank tested, plans for full scale device to test off Orkney	UK
ORECon	*MRC 1000*	*Oscillating Water Column*	http://www.orecon.com/	¼ scale tank test	UK
OWWE (Ocean Wave and Wind Energy)	*Wave Pump Rig*	Point Absorber	http://www.owwe.net/	Tested in Danish wave energy programme 1997 - 2001	Norway

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Pelagic Power AS	*PelagicPower*	Point Absorber	http://www.pelagicpower.com/	Small scale test at Lauvsnes – Norway. In 'Re-design phase)	Norway
Pelamis Wave Power	*Pelamis*	*Attenuator*	http://www.pelamiswave.com/	Commercial farm site at Agucadoura - Portugal. Planning testing of improved device and new Commercial array off Orkney	UK
Renewable Energy Holdings	*CETO*	Point Absorber	http://www.ceto.com.au/home.php	Field tested at Fremantle – Western Australia	AUS / UK
Renewable Energy Pumps	*Wave Water Pump (WWP)*	*Oscillating Water Column*	http://www.renewableenergypumps.com/	Concept	USA
Sara Ltd	*MHD Wave Energy Conversion (MWEC)*	Point Absorber	http://www.sara.com/RAE/ocean_wave.html	Laboratory tested. Developing Ocean concept	USA
SDE	*S.D.E*	*Oscillating Wave Surge Converter*	http://www.sde.co.il/	Full Scale 40kW ocean tested model in Israel	Israel
Sea Power International AB	*Streamturbine*	Unknown	Unknown	Unknown	Sweden
Seabased AB	*Linear generator (Islandsberg project)*	Point Absorber	http://www.seabased.com/	Concept or pilot testing - unclear	Sweden
Seawood Designs Inc	*SurfPower*	Point Absorber	http://www.surfpower.ca/	Concept	Canada
SEEWEC Consortium	*FO3 device, previously as Buldra*	Point Absorber	http://www.seewec.org/index.html	Field tested – single unit in Norway	UK
SeWave Ltd	*OWC*	*Oscillating Water Column*	http://www.sewave.fo/	Concept – demonstration plant planned for 2011	Faroe Islands
SRI International	*Generator utilizing patented electroactive polymer artificial muscle (EPAM) technology*	Biometric Point Absorber	http://www.sri.com/	Concept demonstrations in Florida and California	USA

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Straumekraft AS	*Winch operated buoy*	Point Absorber	http://straumekraft.no/default.aspx	Field test off western Norway	Norway
Swell Fuel	*Lever Operated Pivoting Float*	Point Absorber / attenuator	http://swellfuel.com/	50+ prototypes – research only	USA
SyncWave	*SyncWave*	Point Absorber	http://www.syncwavesystems.com/	Concept	Canada
Trident Energy Ltd, Direct Thrust Designs Ltd	*The Linear Generator*	Point Absorber	http://www.tridentenergy.co.uk/index.php	Field tested off Suffolk coast. Plans for a full test rig in the North Sea 2009	UK
Vortex Oscillation Technology ltd	*Vortex oscillation*	*Attenuator*	http://www.vortexosc.com/modules.php?name=Content&pa=showpage&pid=95	Concept	Russia
Wave Dragon	*Wave Dragon*	*Overtopping Device*	http://www.wavedragon.net/	Prototype tested off Denmark in 2003-05, 2006-08 and final testing to commence in autumn 09 Deployment of test site off Wales in 2011.	Wales / Denmark
Wave Energy	*Seawave Slot-Cone Generator*	*Overtopping Device*	http://www.wavessg.com/	Concept	Norway
Wave Energy Centre (WaVEC)	*Pico plant*	*Oscillating Water Column*	http://www.pico-owc.net/	Plant on Pico Island - Portugal	Portugal
Wave Energy Technologies Inc.	*WET EnGen™*	Point Absorber	http://www.waveenergytech.com/	Field test Small-scale model off Sandy Cove, Nova Scotia, Canada	Canada
Wave Energy Technology	*(WET-NZ)*	Point Absorber	http://www.wavenergy.co.nz/	Field tests on Canterbury coast in 2006	New Zealand
Wave Power Group	*Salter Duck, Sloped IPS*	*Attenuator*	http://www.mech.ed.ac.uk/research/wavepower/	Prototypes tank tested	UK
Wave Star Energy ApS	*Wave Star*	Point Absorber	http://www.wavestarenergy.com/	1:10 model operating since 2006. 500kW machine to be tested from September 2009 – for full deployment in next few years	Denmark

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Waveberg Development	*Waveberg*	Attenuator	http://www.waveberg.com/	Small scale field testing in Nova Scotia, Canada and Cork, Ireland	Canada
WaveBob Limited	*Wave Bob*	Point Absorber	http://www.wavebob.com/	Field Tested in Galway, Ireland	Ireland
Wavegen (Voith & Siemens)	*Limpet*	*Oscillating Water Column*	http://www.wavegen.com/	Installed on the Island of Islay. Currently developing commercial units.	UK
WavePlane Production	*Wave Plane*	*Overtopping Device*	http://www.waveplane.com/	Unknown	Denmark
WindWavesAndSun	*WaveBlanket*	Attenuator	http://www.windwavesandsun.com/	Concept	USA

Summary of tidal devices

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Aquamarine Power / Ocean Flow Energy	Evopod	*Horizontal Axis Turbine – Flexible mooring*	http://www.aquamarinepower.com/ / http://www.oceanflowenergy.com/	1/10 scale prototype Evopod device undergoing sea trials at Strangford Narrows, N. Ireland. 1/5 scale model in development.	UK
Atlantis Resources Corp	Nerus / Solon	*Horizontal Axis Turbine*	http://www.atlantisresourcescorporation.com/	Tow testing has been undertaken. Nerus prototype has been grid connected.	Australia
Balkee Tide and Wave Electricity Generator	TWPEG	*Horizontal Axis Turbine*	N/A	Unknown	Mauritius
BioPower Systems Pty Ltd	bioStream	*Oscillating Hydrofoil – Seabed Mounted*	http://www.biopowersystems.com/	Systems in development (concept)	Australia
Blue Energy	Blue Energy Ocean Turbine (Davis Hydro Turbine)	*Vertical Axis Turbine – Pile Mounted*	http://www.bluenergy.com/	Prototypes tested in Nova Scotia and Florida Gulf Stream.	Canada

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Clean Current Power Systems	Clean Current Tidal Turbine	*Venturi Effect horizontal axis tidal turbine – pile mounted*	http://www.cleancurrent.com/	Field tested in Race Rocks Ecological Reserve, British Columbia	Canada
Edinburgh Designs	Vertical-axs, variable pitch tidal turbine	*Vertical axis tidal turbine – floating*	http://www.edesign.co.uk/	Unknown	UK
Edinburgh University	Polo	*Vertical Axis Turbine*	N/A	Unknown	UK
Fieldstone Tidal Energy	Fieldstone Tidal Energy	*River system device*	http://fieldstoneenergy.com/	Concept	USA
Free Flow 69	Osprey	*Horizontal Axis Turbine*	http://www.freeflow69.com/	Concept	USA
Free Flow 69	Osprey	*Horizontal Axis Turbine / tidal range*	http://www.freeflow69.com/	Concept	USA
GCK Technology	Gorlov Turbine	*Vertical Axis Turbine*	http://www.lucidenergy.com/gck	Small prototypes tested in Maine, Massachusetts, Cape Cod Canal, Brazil and Korea	USA
Greenheat Systems Ltd	Gentec Venturi	*Venturi Effect Horizontal Axis Turbine*	http://www.greenheating.com/page-1.html - page under reconstruction	Unknown	UK
Hammerfest Strom	Tidal Stream Turbine (HS1000)	*Horizontal Axis Turbine – Gravity Base*	http://www.tidevannsenergi.com/	300kW prototype in Kvalsund, Norway. 1MW planned for Scottish waters early 2010	Norway
Hydro Green Energy	Hydrokinetic Turbine	*Venturi Effect Turbines*	http://www.hgenergy.com/	Commercial device deployed at the City of Hastings, Minnesota	USA
Hydro-Gen	Hydro-gen	*Horizontal Axis Floating Paddle Wheel – rigid mooring*	http://www.hydro-gen.fr/	10kW machine has been sea tested. 20kW machine was planned for 2009. 1MW machine planned for 2010.	France
Hydrohelix Energies	hydro-helix	*Venturi Effect Horizontal Axis Turbine – seabed mounted*	http://www.hydrohelix.fr/	Plans for 200kW device	France
Hydroventuri	Rochester Venturi	*Venturi Effect*	http://www.hydroventuri.com/news.php	Operated low head hydro systems in the UK since 2002.	UK

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Ing Arvid Nesheim	Waterturbine	*Vertical Axis Turbine / Hydrofoil*	http://www.anwsite.com/	Concept	Norway
Kinetic Energy Systems	Hydrokinetic Generator, KESC Bowsprit Generator, KESC Tidal Generator	*Horizontal Axis Turbine – Seabed Mounted*	N/A	Unknown	USA
Lunar Energy	Rotech Tidal Turbine	*Venturi Effect Horizontal Axis Turbine – Seabed Mounted*	http://www.lunarenergy.co.uk/	Planned deployment of 1MW device in Korea. 1/3 scale device in sea trials at EMEC.	UK
Marine Current Turbines	Seagen, Seaflow	*Horizontal Axis Turbine – Pile Mounted*	http://www.marineturbines.com/	1.2MW commercial turbine in Strangford Lough, N. Ireland. 10.5MW farm off Anglesey planned. Projects also planned for Nov Scotia, Canada and Anglesey, Wales	UK
Natural Currents	Red Hawk	*Horizontal Axis Turbine*	http://www.naturalcurrents.com/	25kW units developed. Working on larger scale systems.	USA
Neo-Aerodynamic Ltd Company	Neo-Aerodynamic	*Vertical Axis Turbine*	http://www.neo-aerodynamic.com/	Unknown	USA
Neptune Systems	Tide Current Converter	*Superconducting Magnet – Seabed Mounted*	N/A	Unknown	Netherlands
Neptune Renewable Energy Ltd	Proteus	*Venturi Effect Vertical Axis Turbine - Moored*	http://www.neptunerenewableenergy.com/	Concept – 1/10, 1/40 and 1/100 scale models laboratory assessed.	UK
New Energy Crop.	EnCurrent Vertical Axis Hydro Turbine	*Vertical Axis Turbine*	http://www.newenergycorp.ca/	Prototypes tested in Nova Scotia	Canada
Ocean Renewable Power Company	OCGen	*Horizontal Axis Cross Flow Turbine – moored*	http://www.oceanrenewablepower.com/home.htm	1/3 scale prototype tested off Eastport, Maine from 12/07 to 4/08. Further testing planned.	USA
Oceana Energy Company	TIDES	*Horizontal Axis Turbine*	http://www.oceanaenergy.com/	Concept	USA

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
OpenHydro	Open Centre Turbine	*Horizontal Axis Turbine – Seabed Mounted*	http://www.openhydro.com/home.html	Prototype testing in Orkney.	Ireland
Ponte di Archimede	Kobold Turbine	*Vertical Axis Cross Flow Turbine – Seabed Mounted*	http://www.pontediarchimede.it/language_us/	Filed tested in the Strait of Messina, Sicily	Italy
Pulse Generation	Pulse Generators	*Oscillating Hydrofoi – Seabed Mounted / Gravity Base*	http://www.pulsegeneration.co.uk/	100kW device in Humber Estuary powering chemical works.	UK
Robert Gordon University	Sea Snail	*Horizontal Axis Turbine – Hydrofoils used to force to sea floor*	http://www.rgu.ac.uk/cree/general/	"Winkle" tested in Orkney, Sea Snail ready for testing.	UK
Rugged Renewables	Savonius turbine	*Venturi Effect Horizontal Axis Turbine*	N/A	Unknown	UK
Scotrenewables	SRTT (Scotrenewables Tidal Turbine)	*Horizontal Axis Turbine*	http://www.scotrenewables.com/ (Under development)	Testing planned at EMEC	UK
SMD Hydrovision	TiDEL	*Horizontal Axis Turbine – Moored*	http://www.smd.co.uk/	Under development.	UK
Statkraft	Tidevanndkraft	*Horizontal Axis Turbine – Flexible Mooring*	http://www.statkraft.com/	Under development	Norway
Swanturbines Ltd.	Swan Turbine	*Horizontal Axis Turbine – Seabed Mounted*	http://www.swanturbines.co.uk/	Tow Tests completed. 300kW demonstration device to be deployed in EMEC.	UK
Teamwork Tech.	Torcado	*Horizontal Axis Turbine – Pile Mounted*	http://www.teamwork.nl/ / http://www.tocardo.com/	Pre-commercial demonstration in the Netherlands in 2008.	Netherlands
The Engineering Buisiness	Stingray	*Oscillating Hydrofoil – Seabed Mounted*	http://www.engb.com/	Field Tested in the Shetland Islands.	UK
Tidal Electric	Tidal Lagoons	*Tidal Lagoon (horizontal axis turbine) – Seabed Mounted*	http://www.tidalelectric.com/	China Supported 300MW project. Proposed 60MW project in Swansea Bay.	UK/USA

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Tidal Energy Pty Ltd	DHV Turbine	*Vertical Axis cross flow Turbine – Pile Mounted*	http://tidalenergy.net.au/	Unknown	Australia
Tidal Generation Limited	Deep-gen	*Horizontal Axis Turbine – Seabed Mounted*	http://www.tidalgeneration.co.uk/	Planned Tests at EMEC in Orkney – Foundations already in place, nacelle ready for deployment.	UK
Tidal Energy Ltd	Delta Stream	*Horizontal Axis Turbine – Gravity Base*	http://www.tidalenergyltd.co.uk/	Concept	UK
Tidal Sails	Tidal Sails AS	*Oscillating Hydrofoil - Floating*	http://www.tidalsails.com/	Concept	Norway
TidalStream	TidalStream	*Horizontal Axis Turbine – Flexible Mooring*	http://www.tidalstream.co.uk/	Prototype laboratory tested.	UK
UEK Corporation	Underwater Electric Kite	*Horizontal Axis Turbine – Seabed Mounted*	http://www.uekus.com/	Prototype tested in Chesapeake Bay, Ontario.	USA
University of Strathclyde	Contra-rotating marine current turbine	*Horizontal Axis Turbine*	http://www.strath.ac.uk/na-me/	Unknown	UK
Verdant Power	Free Flow Turbine	*Horizontal Axis Turbine – Pile Mounted*	http://www.verdantpower.com/	Prototype, demonstration and 35kW devices in East River, New York – Connected to the Grid. Further projects planned through the Cornwall Ontario River Energy (CORE) Project.	USA
Voith Hydro Ocean Current Technologies	Tidal Current Turbines	*Horizontal Axis Turbine*	http://www.voithhydro.com/vh_en_paa_ocean-energy_tidal-current-power-stations.htm http://www.rwe.com/web/cms/en/204552/rwe-innogy/venture-capital/portfolio/investment-details/	110kw device planned for 2009 off the South Korean Coast. Plans for full scale commercially sized turbines in 2011/2012	UK / Germany

DEVELOPER COMPANY	DEVICE	DEVICE TYPE	Web Site	Status	COUNTRY BASE
Vortex Hydro Energy	VIVACE (Vortex Induced Vibrations Aquatic Clean Energy)	*Horizontal Bar that moves in response to vortex induced vibrations*	http://www.vortexhydroenergy.com/	Prototype undergoing Laboratory testing	USA
Water Wall Turbine	WWTurbine	*Turbine and potential device?*	http://www.wwturbine.com/	No information	USA
Woodshed Technologies - CleanTechCom Ltd	Tidal Delay	*Turbine installed in siphon pipe over/under natural barrier*	http://www.woodshedtechnologies.com.au/about_us.html	Tests Planned at EMEC	Australia / UK

APPENDIX D

REA Assessment Method

REGIONAL ENVIRONMENTAL ASSESSMENT – SCOPING REPORT

REA Assessment Method

Introduction

The following method is to be used to assess the environmental effects of wave and tidal marine renewable devices. The aims of the proposed method are as follows:

- Make a judgement on the potential locations of greatest and least effect on the environment from the installation, operation, maintenance and decommissioning of devices;
- Assess the potential environmental effects of wave and tidal devices based on the development scenarios;
- Provide recommendations for mitigation of the potential effects of the devices on the environment.

It must be noted that the REA will not address detailed issues related to site-specific development. The REA does also not replace the need for targeted studies in relevant areas to assess the impacts of specific developments.

Review of Similar Methodologies

The method used in the assessment, and outlined below, is not definitive. It is also expected that there will be modifications and refinements required to the procedures during the assessment process. The method has been informed by reviewing other similar strategic and regional assessments:

- Scottish Marine Renewables SEA;
- Department of Energy and Climate Change: Offshore Energy Strategic Environmental Assessment;
- Regional Environmental Assessment: a Framework for the Minerals Section.

Approach to the Guernsey Marine Renewables REA Assessment

The Assessment is split into 3 main strands:

- Development of the assessment method;
- Topic based examples of issues for consideration in the assessment;
- Application of the assessment method.

Development of Assessment Method

The method proposed for assessing the effects of the marine devices involves a number of stages. It is important to note that the method is an evolving process. Each stage will interact with and inform other stages. In some situations there may be the need for different parts of the assessment to be revisited, for example if new information is provided.

Assessment Method

The assessment method has 4 main stages:

Stage 0: Identification and agreement of a common set of impact significance criteria
Stage 1: Identification of Generic Effects
Stage 2: Assessment of Effect Significance
Stage 3: Assessment Confidence and Monitoring

Stage 0

The aim of this part of the assessment is to establish a common set of impact significance criteria that may be used across all disciplines in the assessment of the severity of any impacts. This will allow a balanced approach to the comparison of impacts and mitigation measures. For example, a 'severe' impact in relation to Marine Mammals should be comparable with a similarly graded impact in another specialist area such as Benthic Ecology, in terms of its overall impact on the colonies in question. The assessment criteria will be established at a workshop held with specialist contributors prior to commencement of the assessment.

Stage 1

The aim of this part of the assessment is to understand the interaction between a device and a specific topic, e.g. Birds. This is a non geographical assessment and so the information can be applied to any marine environment.

Technology 'envelopes' are to be developed, and these will assist with the identification of the generic effects. These are to be based upon the generic characteristics of the marine renewable devices, some examples of which have already been identified in Chapter 5 of this report. These envelopes will also allow the assessment to take account of any future advances in the technologies and will take account of the entire lifetime of the devices.

Chapter 8 of this report give a summary of generic potential impacts of the marine devices. These effects will form the basis of Stage 1 of the assessment, with more identification of the effects being informed by consultation with experts and reviews of available research.

Stage 2

This looks at the relationship between the generic effects identified in Stage 1 and the marine environment within the study area. The key issues for consideration are:

- Potential effects on REA topic within the study area;
- Identifying the locations of the entities that are affected within the study area;
- Understanding the characteristics of the affected entities and how they interact with the marine environment;
- Identifying whether and Entity is 'sensitive' to the generic effects;
- Assessing the significance of the effects;
- Assessing the likelihood of an effect occurring;
- Identifying mitigation measures that can be used to reduce, avoid or offset potentially significant impacts.

There are three main types of mitigation that could be applied to the assessment of the devices:

- Mitigation incorporated into the device and siting of a development;
- Mitigation based on the implementation of protection measures;
- Recognised mitigation measures

Given that the REA is being undertaken at a still early stage of marine renewable device development it is very hard to know what measure could be incorporated into the design of a device. As well as this, the REA does not know the types of mitigation measures that would be derived from mare detailed assessments, such as a targeted EIS. As such, these two mitigation methods cannot be used to inform the assessment of the significance of an effect.

Recognised mitigation measures include:

- Seasonal Restrictions on device installations (such as the avoidance of breeding seasons);
- 500m avoidance zones around pipelines and cables.

Given that these measures are recognised by developers and standard approaches to their application have been developed for a range of developments, these measures can be used to inform the assessment of the significance of an effect.

Stage 3

There is a potential risk that there will be insufficient information available to determine exactly how the devices may affect a given REA topic. The use of the aforementioned technology envelopes will help to reduce any potential risk of error and so increase the assessment confidence.

As well as the potential unknowns with the devices, the REA is to take into account potential gaps in baseline data. As the marine environment is, when compared to the terrestrial environment, relatively inaccessible, the understanding of its characteristics and interactions are limited. Most information for marine environments has either been collected as part of a specific development or study of interest. Information on the uses of the marine environment, such as navigation or recreation, is much more detailed.

Based on the assessment confidence, monitoring will be suggested to fill in the gaps with the baseline data and to improve the levels of understanding of the effects of the marine devices. This part will also identify areas of additional investigation that can be undertaken to increase the levels of understanding of the way the devices interact with the marine environment.

Where significant additional datasets become available, such as new work on the effect of marine devices on collisions or the distribution of fish, the REA could revisit and reassess the potential effects.

Examples of Topic-Based Issues for Consideration in the Assessment

The second part of the assessment method is the identification of topic based issues. Below is a list of example issues, which are not definitive and may be subject to refinement as the assessment process evolves.

Geology and Sediment Transition

The assessment of effects of wave and tidal devices on marine processes and geology is complex. The assessment of effect significance will be based on 4 points, the scale of the effect, effects on the sediment process, changes in levels of sediment suspension and site vulnerability.

Where possible, any arrays where the REA finds that energy regimes will be adversely affected, due to siting of devices, will be mapped and considered in the assessment of development scenarios.

It is the indirect effects that changes in sediment regimes, amongst others, may have on benthic communities that is a key issue connected with this effect. As such, information from this aspect of the assessment will be fed directly into the biological section of the environmental assessment.

Marine Mammals

The assessment will take into account species distribution and activities such as feeding (although there may not be information on specific feeding grounds, any information available on how and when mammals feed will be taken into account), breeding, communication, migrations and abundance. There is not an existing data set that covers all of the above information to a consistent level. However, there is high-level information available on each aspect that can be fed into the assessment. The prediction of specific effects on marine mammals will be based on current understanding of behaviour and assumptions of their reactions with regards to turbines. It will not use evidence specifically related to mammals interactions with devices as there is currently no field-data.

Commercial Fisheries

The assessment of effects on commercial fisheries will take into account the amount of fishing taking place and fishing types (e.g. pelagic, demersal, potting and shell fisheries). The assessment will also take into account seasonal variations in activity. However, any information that is provided by fishermen through the scoping process on the location of key fishing grounds will be included in the assessment.

Important area for fishing can change rapidly and fishing methods and locations are very variable. It will therefore be acknowledged in the assessment that more detailed location specific studies will have to be undertaken for individual developments through the project EIA process.

Marine and Coastal Historic Environment

The assessment on areas of potential marine archaeological importance will consider potential sites of submerged landscapes and wrecks. However, it can be assumed that developers will generally avoid wrecks due to the potential difficulties associated with the installation of devices close to wrecks. Any exclusion areas for protected wrecks will also be taken into account. For the purpose of the assessment a risk based approach should be adopted with regards to wrecks and the area buffered around them. This approach should take into account the size of the wreck, such as from a lone cannon up to a full sunken ship, the condition that the wreck is in and the seabed and tidal conditions to assess the dispersal range around the wreck. The method of device deployment also needs to be considered along with the accuracy of the vessel control. All of these factors should be used to asses each wreck on an individual basis in order to ascertain an appropriate exclusion zone

Shipping and Navigation

The effects of devices on shipping is well understood, mainly obstruction and collision. The key issue will be identifying shipping routes of importance within the study area, and their location, width etc. The data ShipRoutes data acquired gives a good overview of key shipping routes and densities, but the routes shown are indicative and not fully representative of the routes taken by vessels. However additional data via the AIS network will also be considered in the assessment giving a more useful mapping of shipping routes.

Recreation

The assessment of effects on recreation will take into account seasonality and key areas of interest.

Application of the Assessment Method

This will be applied in two levels:

Level 1: Assessment of individual arrays (technology envelopes)
Level 2: Assessment of the development scenarios.

Level 1

The main aim of the REA is to assess the impact 260MW+ (the maximum development) and 100MW (the minimum development to meet targets) of marine renewable energy capacity being installed and operating in the Bailiwick of Guernsey on the environment. Based on this the REA will focus on Marine device arrays as these will be the developments that contribute to the electricity production.

The study area will be split into a number of 'development areas', which have been identified as:

1. The Big Russel;
2. The Little Russel;
3. St Martin's Point;
4. East of Sark;
5. The North of Guernsey;
6. The Northwest Coast;
7. The West coast;

This will improve the ease of analysis as well as increasing the clarity of the results. A detailed description of the identification of the study area is in Chapter 6. The areas are presented in Figure 6.1 in Chapter 6. The areas will be assessed for either one device type or multiple device types depending upon the resource available in the area.

The presentation of the results is complex due to the large area of study, the wide range of devices and arrays and the levels of uncertainty involved with the prediction of the effect a device, or array, will have on the environment.

A key objective of the REA is to advise the development of renewable energy in Guernsey and to inform the decision making process. This must be shown by the results. As such, where practical, it will be useful to utilise maps to illustrate the results of the assessment, which will make the results clear and accessible.

Significance mapping will be used to highlight the areas of significance, at all levels from slightly to highly significant effects, for specific receptors. For example a shipping routes map would have the routes highlighted in different colours identifying the significance of an effect.

Level 2

Once the assessment of the arrays has been completed, the REA will consider the cumulative effects of the development scenarios. The six development scenarios that have been developed, as stated in Chapter 2, are:

1. Unconstrained development: development of all tidal and wave resources in all reasonable sites – development of all arrays as outlined above;
2. Development of only tidal stream arrays;
3. Development of only wave arrays;
4. Development in areas of greatest resource (provisionally the northwest coast of Guernsey and the Big and Little Russel);
5. Development of a single array;
6. No development (‘Do Nothing’ Scenario).

The potential grid connections will also be assessed as part of the REA to determine whether there would be an adverse effect on the environment.
The development scenarios will be assessed in two stages as part of the REA:

1. Application of the development scenarios to a development area – calculation of the electoral output that could be generated from each of the development areas based on the development scenarios;
2. Application of the development scenarios to the whole study area – calculation of the potential energy outputs for the study area based on application of the development scenarios, including the cumulative effects that may occur with clusters of devices.

Due to the few numbers of commercial wave and tidal developments, there is a level of uncertainty surrounding the output of wave devices and therefore that of arrays and array size. The energy capacity for wave and tidal devices can vary largely, from well below 1MW to, potential, 5MW+. However, it has been decided that for the sake of the REA an average generating capacity of 1MW per device will be used per device.

The electricity generating potential for each given location will be measured by using the above assumptions and the development scenarios. This will then be assessed considering development in areas where there are:

- No or on slightly significant effects on the environment following mitigation;

- No, slightly or moderately significant effects on the environment following mitigation;
- No, slightly, moderately or highly significant effects on the environment following mitigation.

To apply the development scenarios to the whole study area the assessment aims to find out whether the deployment of devices to generate 200MW of electricity can be generated in areas there will be no or only slightly significant effects, or whether to meet the target development may have to be situated in areas of higher significant effects.

APPENDIX E

Tidal Resources Assessment

Tidal Stream Resource Assessment for The Channel Islands area

For Black & Veatch Consulting Limited

By Alan Owen, The Robert Gordon University, Aberdeen

This report was prepared by The Robert Gordon University for Black & Veatch Consulting Limited for their sole use. It is based on an indicative model using information available in the public domain.

30/03/05

Introduction

Black & Veatch Consulting Limited (B&V) has recently reviewed estimates of tidal stream resources and the techniques used therein. One particular report that considered UK sites in detail has been examined closely. The 1993 ETSU report [3] was generated using the tidal stream 'farm' methodology, which assumes that a grid of devices is installed and that the extractable energy is a function of the installed capacity. Whilst this method is broadly applicable to wind farms, it is not suitable for tidal stream energy exploitation due to the fact that it is possible for the calculated energy output to exceed the energy available.

An alternative method is being developed by The Robert Gordon University in which, the total energy flux through a site is calculated based on existing empirical data available in the public domain. Having defined the total energy flux available, the Significant Impact Factor (SIF) parameterises the exploitable energy, which seeks to determine the maximum energy that may be extracted without causing significant changes to the flow regime. The SIF has been tentatively set at 20% as an average figure, and it is considered that the figure will be site specific and dependent on flow drivers, bathymetry and other physical conditions. This report looks at the resource within the Channel Islands area and contrasts the results from the new flux methodology, with the 1993 report based on the farm methodology.

Methodology

The accuracy and cost effectiveness of the method depends on the ready availability of data, which has already been validated and is generally accepted as being reasonably accurate. Pictorial data can be found from a variety of publications including bathymetry from British Geological Survey maps and tidal stream vectors from the Admiralty Tidal Stream Atlas.

For the Channel Islands study, bathymetry data was used from BGS Sheet 49N 04W (Guernsey) [1], Admiralty Chart 2669, and tidal stream data was taken from Admiralty Tidal Stream Atlas NP264 (Channel Islands) [2]

Bathymetry

The bathymetry image is stripped of all information not required by the programme, leaving only contour lines and landmasses identified. The bathymetry is defined using individual colours for each of the bathymetric contours and for the landmasses, leaving the spaces in between as unknowns. The programme then scans the picture and generates an array of numerical contour values from the colour found at each vertex, using a linear interpolation algorithm to produce values for the vertices where no colour is identified.

Tidal stream data

In a tidal stream atlas the vectors are usually scaled in groups according to the strength of the flow that they represent and the programme allows for this by providing a vector scaling capability. For the Channel Islands however, this is not the case, and each vector has to be individually specified. The effects of flow momentum between the head of one vector and the tail of preceding vectors can also be modelled according to the strength of flow. The vector field (Fig.1) is input by overlaying the relevant tidal stream vector image over the bathymetric contour image and using the mouse click event to indicate the start and end points of each vector. These start and end points, along with variables indicating the strength of flow and momentum effects, are stored in a list box to be processed later in the programme. Outlines of landmasses are used to check the alignment of the vector map when overlaid onto the bathymetry graphic using the Visual Basic overlay command. Any land mass is given a zero vector value and boundary conditions for the graphics' edge are found by using an average value of the nearest available vectors.

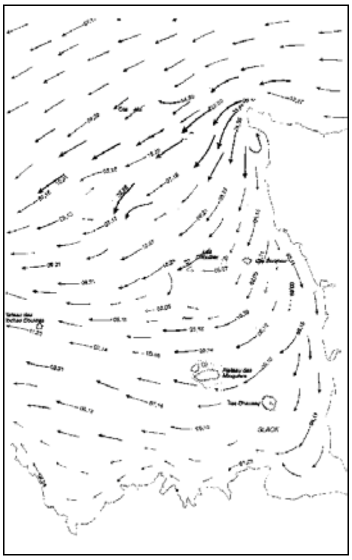

Figure 1 Tidal stream vectors for Channel Isles

The programme first identifies what information it has available to it by scanning the image, recognising any landmasses present, and imports the flow vectors from the listbox which holds the values defining the vector start and finish co-ordinates. The vector magnitude is then modified according to the user-defined variables describing the strength of flow and momentum effects. Before continuing, the known flow vectors and their associated momentum vectors, are drawn for approval and/or modification by the user. The programme then scans the picture, attaching known vector X and Y component values at each vertex, interpolating for any missing values and passing the results to an array, the coordinates of which coincides with the bathymetric coordinate system. The X and Y vector components are stored in separate arrays in order to reduce the number of string splitting and re-assembling operations. Once the interpolation process is complete, the vector components are smoothed by averaging over surrounding values to a maximum distance set by the user. Zero value vector components attached to landmasses are reasserted at this point to prevent the algorithmic erosion of the coastlines.

The vectors are assembled and their magnitude and direction (in degrees) are written to a final array for visual interpretation, printing to file etc. The image is then redrawn using the vector magnitude to govern the colour used in the image i.e. white (RGB(255,255,255)) indicates <0.05m/s flow and black(RGB(0,0,0)) indicates a flow speed in excess of 6m/s. (see fig.2 overleaf)

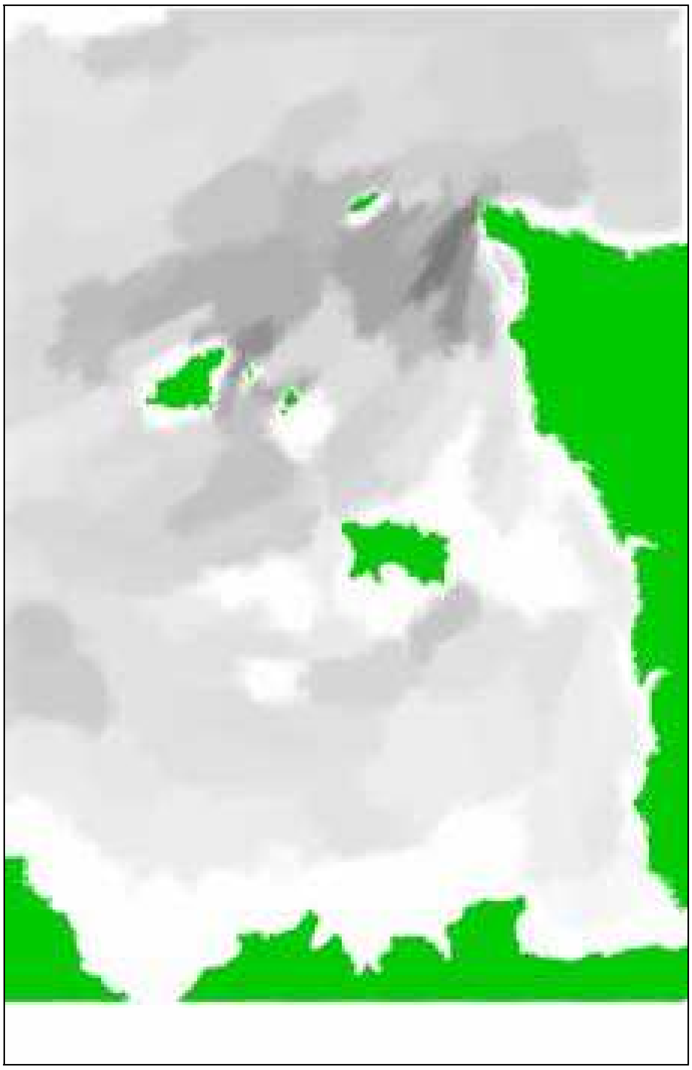

Figure 2 Greyscale flow map through Channel Isles

Combining Bathymetry and Flow Vectors

At this point, there exists a number of arrays holding information on flow speed and flow direction for each 1 hour period of the flow/ebb cycle as well as the bathymetry and land masses, all of which use the same X, Y co-ordinate system. Therefore at any given vertex (or vertices) linked information can be utilised. For example, if the surface velocity is known, and assuming that the surface flow is indicative of the flow profile, a reasonably representative flow profile can be obtained using the $1/7^{th}$ power law. Applying the power law to describe the flow profile with respect to depth, the programme creates a quasi-3D velocity matrix, which can be queried for a variety of data. For example, the data can provide information on the energy flux through any chosen cross section on the image or calculate the CSA of the flow at any point.

Time series interpolation

In this study, the data files for each one-hour interval are read into the program and assembled into a three-dimensional array. By extracting the data at any chosen section, a 13-point, approximately 1-hour interval, time series is found for the tidal stream velocities at that section, (in actual fact the flow/ebb cycle is generally taken as being 12.5 hours). Application of a second order Lagrange interpolating polynomial generates intermediate values at quarter hour intervals. Similarly, for the 14-day Spring/Neap cycle, tide tables provide twice daily high water and low water values for a nearby port that can be used to model the cyclical variation of the tidal stream velocities at the point. Taking the difference between the HW and LW heights and normalising for the Spring peak, gives a factor which, when applied to the Spring values used by the program, models the Spring/Neap cycle from Spring values only.
Between each vertex in the cross section, which on the scale used, represents a distance of 210m, the power is calculated as follows:-

The program has generated X and Y vector components at each vertex (*Xvect, Yvect*), from which, the velocity vector (V_{vel}) may be defined.

$$V_{vel} = \sqrt{(X_{vect}^{2} + Y_{vect}^{2})} \qquad \text{eqn 1}$$

The length of the section can be found from the start and finish X,Y co-ordinates,

$$L_{section} = \sqrt{(X_{start}^{2} - X_{end}^{2}) + (Y_{start}^{2} - Y_{end}^{2})} \qquad \text{eqn 2}$$

The CSA (*A*) is defined by the scale width (210), the length of the section in terms of the graphics X,Y co-ordinates and the section depth (*D*) at the vertex, ie

$$A = 210 * D * L_{section} \qquad \text{eqn 3}$$

To obtain hourly power (Whr) figures through the section from ¼ hour intervals, eqn 4 is used for each ¼ hour interval and the sum taken of four consecutive intervals.

$$P = 0.5 * \rho * A * V_{vel}^{3} \qquad \text{eqn 4}$$

The resulting hourly figures are summed for the 13 hr flood/ebb cycle giving a total power flux through the section in Whr per flood/ebb cycle.

$$P_{FE} = \sum_{1}^{13} P \qquad \text{eqn 5}$$

These power totals are then transferred to a spreadsheet where the equivalent velocity that would be required to generate that power in that period is calculated from the total power flux, ie

$$V_{eq} = \sqrt[3]{(P_{FE} / (0.5 * \rho * A)} \qquad \textit{eqn 6}$$

The ratio of high water to low water for a nearby port eg St Helier, provides a reasonable model for the Spring/Neap cycle. Normalising the ratio to the Spring maximum gives a factor (γ), which may be applied to the 14 day cycle. Using St Helier as a pattern, this factor can be calculated for each site from the Spring/Neap values in the Tidal Stream Atlas

Data taken from Tide Table St Helier, Jersey, 49.1667N,2.1000W

	Spring/Neap ratio for site	2.26		1.88		1.97	
	HW limit for site (m)	11.24		11.24		11.24	
	LW as proportion of HW	0.442478		0.531915		0.507614	
	Low water limit for site (m)	4.973451		5.978723		5.705584	
	HW/LW range for site (m)	6.266549		5.261277		5.534416	
St Helier HW-LW (m)	Normalised	CSEC1 (HW-LW, (m))	Normalised(γ)	CSEC2 (HW-LW, (m))	Normalised(γ)	CSEC3 (HW-LW, (m))	Normalised (γ)
8.69	0.773132	9.10	0.81	9.44	0.84	9.35	0.83
8.28	0.736655	8.75	0.78	9.15	0.81	9.04	0.80
7.73	0.687722	8.29	0.74	8.76	0.78	8.64	0.77
7.19	0.63968	7.84	0.70	8.38	0.75	8.24	0.73
6.47	0.575623	7.23	0.64	7.88	0.70	7.70	0.69
5.81	0.516904	6.68	0.59	7.41	0.66	7.21	0.64
5.04	0.448399	6.03	0.54	6.87	0.61	6.64	0.59
4.59	0.408363	5.65	0.50	6.55	0.58	6.31	0.56
4.29	0.381673	5.40	0.48	6.34	0.56	6.08	0.54
3.78	0.336299	4.97	0.44	5.98	0.53	5.71	0.51
4.14	0.368327	5.28	0.47	6.23	0.55	5.97	0.53
4.31	0.383452	5.42	0.48	6.35	0.57	6.10	0.54
5.42	0.482206	6.35	0.57	7.14	0.63	6.92	0.62
5.91	0.525801	6.76	0.60	7.48	0.67	7.29	0.65
7.25	0.645018	7.89	0.70	8.43	0.75	8.28	0.74
7.68	0.683274	8.25	0.73	8.73	0.78	8.60	0.77
9	0.800712	9.36	0.83	9.66	0.86	9.58	0.85
9.2	0.818505	9.53	0.85	9.80	0.87	9.73	0.87
10.35	0.920819	10.49	0.93	10.61	0.94	10.58	0.94
10.24	0.911032	10.40	0.93	10.53	0.94	10.50	0.93
11.12	0.989324	11.14	0.99	11.16	0.99	11.15	0.99
10.7	0.951957	10.79	0.96	10.86	0.97	10.84	0.96
11.24	1	11.24	1.00	11.24	1.00	11.24	1.00
10.58	0.941281	10.69	0.95	10.77	0.96	10.75	0.96
10.73	0.954626	10.81	0.96	10.88	0.97	10.86	0.97
9.92	0.882562	10.13	0.90	10.31	0.92	10.26	0.91
9.68	0.86121	9.93	0.88	10.14	0.90	10.08	0.90
8.84	0.786477	9.22	0.82	9.55	0.85	9.46	0.84

Table 1 HW/LW difference, normalised to spring peak
Ref: http://www.mobilegeographics.com:81/calendar/month/5470.html

Since the equivalent velocity V_{eq} represents the velocity required to generate the calculated power through any given section at Spring peak over a period of 13 hrs, variation of this velocity in proportion to the difference between high water and low water (Combined Normalised (γ) in table 1 above), will permit a reasonable approximation of the velocity variation with the Spring/Neap cycle (eqn 7). The resulting total, (P_{cycle}) multiplied by 26 will give an annual power output, (P_{annual}), at the section, based on the Spring peak V_{eq} for that section. (eqn 8).

$$P_{cycle} = \sum_{1}^{28} 0.5 * \rho * A * (\gamma * V_{eq})^3 \qquad \textit{eqn 7}$$

$$P_{annual} = P_{cycle} * 26 \text{ (GWhr)} \qquad \textit{eqn 8}$$

Whilst the method is clearly an approximation, it does accommodate the variations both within the flood/ebb cycle and the Spring/Neap cycle, based on 15 minute intervals.

Define Area & sections

For the purposes of this study, the general area to be examined is outlined by the lat/long co-ordinates, 48.500°N, 1.500°W to 50.000° N, 3.000° W (fig.3 overleaf). Six sites are identified, five of which were previously assessed in [3]. This methodology generates comparative data for these five sites.

The cross sections considered to be of interest for this study are illustrated in fig 3 overleaf and listed below:-

CSEC1: Guernsey (49.416°N, 2.633°W) to Pte de l'Arcouest (48.816°N, 3.000°W)
Broad cross section of medium speed flow.

CSEC2: Race of Alderney, (49.720°N, 2.14°W) to (49.705°N, 2.067°W) , compared with Site 16 – Race of Alderney, [3]

CSEC3: Big Russel, Guernsey (49.460°N, 2.445°W) to (49.440°N, 2.390°W)
Compared with Site 19 – Big Russel

CSEC4: North East Jersey, (49.250°N, 2.060°W) to (49.273°N, 2.040°W)
Compared with Site 20 – North East Jersey

CSEC5: Casquets, Channel Islands, (49.748°N, 2.398°W) to (49.811°N, 2.472°W)
Compared with site 17 – Casquets

CSEC6: NW Guernsey (49.602°N, 2.791°W) to (49.517°N, 2.700°W)
Compared with Site 18 - North West Guernsey

The Lat/Long co-ordinates are converted to X,Y co-ordinates in relation to the graphic. Note that for ease of manipulation the X,Y coordinates are aligned with the Visual Basic system, which denotes the origin (0,0) as top left.

	X	Y	Lat	Long	X	Y	Lat	Long
CSEC1	113	273	49.416	2.633	3	553	48.816	3
CSEC2	264	131	49.72	2.14	287	138	49.705	2.067
CSEC3	171	252	49.46	2.445	187	262	49.44	2.39
CSEC4	289	350	49.25	2.06	295	340	49.273	2.04
CSEC5	185	118	49.748	2.398	162	88	49.811	2.472
CSEC6	64	186	49.602	2.791	92	226	49.517	2.7

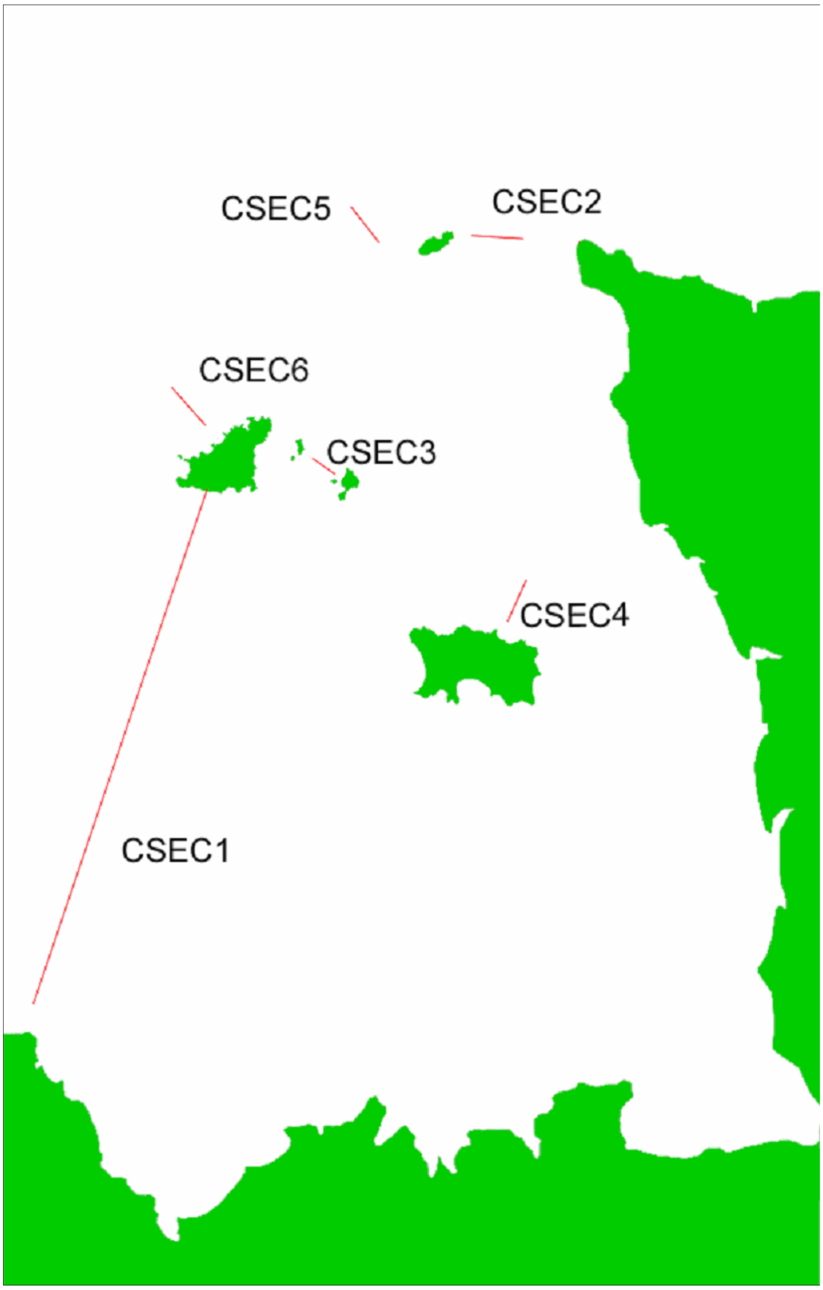

Figure 3
Approximate illustrative locations of the various sections.

The site graphic as used by the program measures 461(W) x 724(H), producing data at 333764 vertices with depths varying from 0m to 80m, in increments of 1m.
CSEC1 was chosen for its approximate perpendicularity to the average flow for the majority of the tidal cycle and because initial visual inspection suggested a phase difference would be found between this and CSEC2. The remaining sections were taken for the purposes of comparison with the 1993 report. [3]

Results

Model Validation

The model is run for each image combination representing 13 x 1hour (approx) intervals of the tidal cycle. The resulting greyscale image is then checked for correlation with the known values as given in the Tidal Stream Atlas. By clicking on the image, a text box shows the X,Y co-ordinates at the point and displays the vector speed and direction at that point. In previous work, (Pentland Firth and The Orkney Islands), the vectors are scaled to a reasonable level of accuracy. In the case of the Channel Islands, no scaling was inherent within the vector images and each image was tuned individually to a variation of +/- 5%. The section between Guernsey and Alderney was not included since, when viewed with the direction of flow, the CSA available for most of the tidal cycle is minimal. Also, in its present configuration, the methodology is not yet comparing flow direction with the relative direction of the chosen section, although this will be available in future versions. The methodology examines the flux at the boundary, regardless of direction, and assumes that any energy extraction method would be capable of aligning itself with the prevailing flow.

The AVI file below shows the flux represented in greyscale over the 13 hour period at 1 hour intervals.

Results

The output from the software is collated into tables (see appendix), which provides numerical values for the Channel Islands tidal resource. Figures shown in brackets refer to those available in the 1993 report.

CSEC1: Guernsey (49.416°N, 2.633°W) to Pte de l'Arcouest (48.816°N, 3.000°W)

The site covers a broad spread of variable speed flow between the north coast of France and the south coast of Guernsey, and is primarily driven by the head difference between the Baie du Mont Saint Michel and the English Channel.

Bathymetry

The maximum depth is found as 60m, which correlates well with Chart 2669. Average depth is 53m and the width of the section is 63210m

Velocities

Peak flow speed across this section is given as 2.09m/s at +4hrs(HW, Dover) by the program, which compares with 2.15m/s at +4hrs(HW, Dover) shown in the Tidal Stream Atlas. Peak spring/neap ratio is 2.26.

Resource

Total flux across the section is 8491 GWhr/yr. If a 20% SIF is assumed, this suggests an available resource of 1698 GWhr/yr. Annual power as a function of CSA is 2.75 MWhr/m^2

CSEC2: Race of Alderney, (49.720°N, 2.14°W) to (49.705°N, 2.067°W) , compared with Site 16 – Race of Alderney, [3]

Bathymetry

The maximum depth is found as 46m, which correlates reasonably well with Chart 2669 giving a spot depth of 42m. Average depth is 40.1m and the width of the section is 4936m

Velocities

Peak flow speed across this section is given as 4.5 m/s (4.4m/s) at -3hrs(HW, Dover) by the program, which compares with 4.4 m/s at -3hrs(HW, Dover) or 4.8 m/s at -4hrs (HW, Dover) shown in the Tidal Stream Atlas. Peak spring/neap ratio is 1.88 (1.82).

Resource

Total flux across the section is 3628 GWhr/yr. If a 20% SIF is assumed, this suggests an available resource of 726 Whr/yr (5187 GWhr/yr). Annual power as a function of CSA is 18.3 MWhr/m^2

CSEC3: Big Russel, Guernsey (49.460°N, 2.445°W) to (49.440°N, 2.390°W)

Compared with Site 19 – Big Russel

Bathymetry

The maximum depth is found as 36.6m, which correlates well with Chart 2669 giving a maximum spot depth of 37m. Average depth is 24.5m and the width of the section is 4056m

Velocities

Peak flow speed across this section is given as 2.6 m/s (2.8m/s) at -5hrs(HW, Dover) by the program, which compares with 2.6 m/s at -5hrs(HW, Dover) shown in the Tidal Stream Atlas. Peak spring/neap ratio is 1.97 (n/a).

Resource

Total flux across the section is 822 GWhr/yr. If a 20% SIF is assumed, this suggests an available resource of 164 GWhr/yr (2000 GWhr/yr). Annual power as a function of CSA is 8.3 $MWhr/m^2$

CSEC4: North East Jersey, (49.250°N, 2.060°W) to (49.273°N, 2.040°W)

Compared with Site 20 – North East Jersey

Bathymetry

The maximum depth is found as 20m, which correlates well with Chart 2669 giving a maximum spot depth of 23m. Average depth is 20m and the width of the section is 2599m

Velocities

Peak flow speed across this section is given as 2.6 m/s (3.1m/s) at +4hrs(HW, Dover) by the program, which compares with 2.6 m/s at +4hrs(HW, Dover) shown in the Tidal Stream Atlas. Peak spring/neap ratio is 1.8. (1.8)

Resource

Total flux across the section is 282 GWhr/yr . If a 20% SIF is assumed, this suggests an available resource of 56 GWhr/yr (1403 GWhr/yr). Annual power as a function of CSA is 5.43 $MWhr/m^2$

CSEC5: Casquets, Channel Islands, (49.748°N, 2.398°W) to (49.811°N, 2.472°W)

Compared with site 17 – Casquets

Bathymetry

The maximum depth is found as 71.6m, which correlates reasonably well with Chart 2669 giving a maximum spot depth of 79m. Average depth is 70.1m and the width of the section is 7810m.

Velocities

Peak flow speed across this section is given as 2.4 m/s (2.6m/s) at -4hrs(HW, Dover) by the program, though there is no immediate figure shown in the Tidal Stream Atlas, the closest suggests 1.95m/s at –3hrs(HW, Dover). Likewise, peak spring/neap ratio is approximately 1.8. (1.85)

Resource

Total flux across the section is 2933 GWhr/yr. If a 20% SIF is assumed, this suggests an available resource of 587 GWhr/yr (2943 GWhr/yr). Annual power as a function of CSA is 5.36 $MWhr/m^2$

CSEC6: NW Guernsey (49.602°N, 2.791°W) to (49.517°N, 2.700°W)

Compared with Site 18 - North West Guernsey

Bathymetry

The maximum depth is found as 70m, which correlates well with Chart 2669 giving a maximum spot depth of 65m. Average depth is 69.7m and the width of the section is 10199m.

Velocities

Peak flow speed across this section is given as 2.1 m/s (2.1m/s) at +2hrs(HW, Dover) by the program, which compares with 2.05 m/s at +2hrs(HW, Dover) shown in the Tidal Stream Atlas. Peak spring/neap ratio is 2.6. (1.85)

Resource

Total flux across the section is 2530 GWhr/yr. If a 20% SIF is assumed, this suggests an available resource of 506 GWhr/yr (4402 GWhr/yr). Annual power as a function of CSA is 3.56 $MWhr/m^2$

Discussion

The program output generally achieves a high degree of correlation with the Tidal Stream Atlas, and the bathymetry and flow dimensions of the 1993 report. Whilst the 1993 report mentions installed capacity and resulting output, it is likely that the 1993 report assumed a much higher level of installed capacity than would be considered now.

It is apparent from the Tidal Stream Atlas that the Channel Islands area partially behaves in a manner analogous to a sea loch, in that the flow is forced towards the Baie du Mont Saint Michel where it is held by the tide rising in the English Channel. Some of the flow which passes through CSEC2 is from the periphery of the English Channel flow at +6,–6,-5, +1,+2,(hrs relative to HW @ Dover) whilst at –4,-3,-2,-1,HW,+3,+4,+5,+6, the site is filling and draining with a change in head, rather than running as a channelled flow. It is therefore very likely that the proposed SIF of approximately 20% may be different for the sites within this area. Extraction of energy from this area would impact on the performance of the barrage at La Rance, since energy extraction would change the head available at the barrage site.

The overall spring/neap ratio is not constant for the sites within the area, varying from 2.94 at HW Dover, to 1.76 at +5Hrs(HW, Dover). The Race of Alderney (CSEC2) provides the best power availability per m^2, with an annual average of 18.31 $MWhr/m^2$.

This study models the power available at each site when considered individually, but CSEC2 and CSEC3 are interdependent as are CSEC5 and CSEC6. Their interdependency varies through the flood/ebb cycle, i.e. for both pairs of sites, no interdependency exists at HW-2 and HW-1, when there is little flow present through either, but major interdependency exists at HW-5 and HW-4, when there are large flows through both.
Further modelling is required to establish the true power resource for the Channel Islands, but a reasonable approximation is of the order of 1.5 – 2.5 TWhr/yr, assuming an SIF of 20%.
The model itself appears to obtain reasonably accurate flow velocities but requires a more flexible algorithm for interpolating the bathymetry.

Conclusions

The graphical flux method is relatively quick to produce results but relies entirely on the accuracy of the original data. However, the data employed is as measured by the Hydrographic Office rather than produced by theoretical equations as used in more sophisticated CFD packages. The correlation with the measured data on the vector graphics is generally of the order of +/- 5% and therefore is considered to be a reasonable reflection of the flow as mapped. It is not possible to take into account any shear flows at depth, and these would need to be determined by site measurements.

The Channel Islands area appears to offer a usable resource of 1.5 – 2.5 TWhr/yr based on the proposed SIF of 20%, but exploitation at one site will have an effect on neighbouring or downstream sites. Exploitation on any commercial scale will affect the HW/LW cycle at the existing tidal barrage site at La Rance. More accurate modelling of the effects of energy extraction on the head is required to quantify this effect. This study has excluded the area between Alderney and Guernsey, since the energy extracted at this point would largely be available at the other sites.

References

1. BGS Map, Guernsey Sheet 49N 04W, Scale 1:250000, NERC
2. Admiralty Tidal Stream Atlas NP264 (Channel Islands) 1993, ISBN 0707712645
3. ETSU Tidal Stream Energy Review, Report T/05/00155/REP, 1993