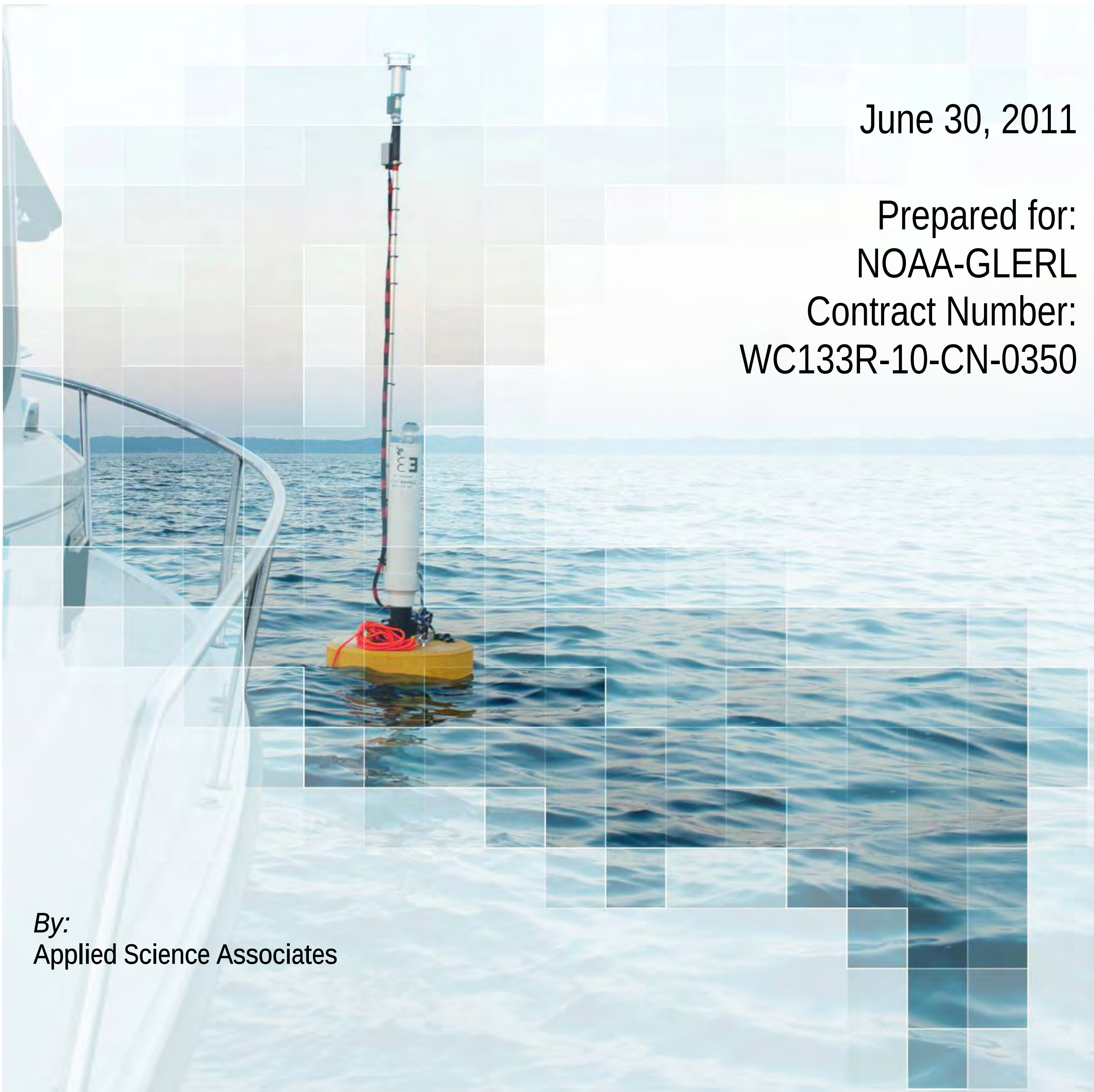
TECHNICAL MEMORANDUM 1: CURRENT STATE OF DATA MANAGEMENT IN SUPPORT OF OBSERVING SYSTEMS

Near-Term Design of the Great Lakes Observing System Enterprise Architecture



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4.2.4 Wisconsin Department of Natural Resources (WDNR)

WDNR participates in the Lakewide Management Plan (LaMP) program monitoring pollutants at locations throughout the Great Lakes tributary area of Wisconsin. WDNR also monitors *Cladophora* and nutrients in the near-shore areas in conjuction with the University of Wisconsin – Milwaukee Water Institute. Also tributaries to Lake Superior are monitored for suspended solids and flow to evaluate upstream BMPs and BMP pollutant reductions in the watershed.

Additionally, WDNR is examining phosphorus loading from major tributaries to Lake Michigan including the Fox River, Milwaukee River, Manitowoc River, Menominee River, and Sheboygan River. These sites are sampled monthly and during storm events.

4.2.5 University of Wisconsin - Oshkosh

In cooperation with the WDNR, University of Wisconsin – Oshkosh performs bacteria monitoring to inform beach closure decisions on Lake Michigan.

4.2.6 GVSU – Annis Water Resources Institute

Grand Valley State University has several monitoring programs in the near-shore area of the Great Lakes. In conjunction with the EPA Great Lakes National Program Office (GLNPO), GVSU has established a long-term observatory in Muskegon Lake to monitor water quality and ecological changes.

4.2.7 Green Bay Metropolitan Sewerage District

Green Bay Metropolitan Sewerage District conducts bacteria at several locations along the Fox River and Green Bay in conjunction with the Brown County Health Department. They also operate continuous monitoring stations for a variety of constituents in both the Fox River and Green Bay.

4.2.8 Milwaukee Metropolitan Sewerage District

Milwaukee Metropolitan Sewerage District conducts monitoring and surveys at several locations in Lake Michigan including an Outer Harbor Survey, South Shore Survey, and Nearshore Survey. These surveys provide information on the impact of MMSD’s wastewater treatment plants and the Milwaukee, Menomonee, and Kinnickinnic rivers on water quality in Lake Michigan. MMSD also surveys several tributary rivers to Lake Michigan for a range of physical and chemical parameters.

4.2.9 Heidelberg College

Heidelberg College operates the Ohio Tributary Monitoring Program to quantify nonpoint pollutants flowing into Lake Erie. The program has sampling locations collocated with USGS stream gaging stations and monitors a range of physical parameters, nutrients, and herbicides.

5. REFERENCES:

Aronoff, Stan. 2005. Remote Sensing for GIS Managers. ESRI Press, Redlands, CA. 487 pp.

Falkner, Edgar. 1995. Aerial Mapping: Methods and Applications. Lewis Publishers – CRC Press, Boca Raton, FL. 322 pp.

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APPENDIX A
REAL-TIME STATIONS LIST

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Table A1 Inventory of Real-Time Stations

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1314	AOS	AES	EC	WSI	Simcoe ONT	42.85000	-80.27000	No
1315	AOS	AES	EC	YTJ	Terrace Bay ONT	48.78000	-87.10000	No
1013	Buoy	AES	EC	45132	Canada AES Buoy 02	42.47000	-81.22000	Yes
1014	Buoy	AES	EC	45135	Canada AES Buoy 05	43.79000	-76.87000	Yes
1015	Buoy	AES	EC	45136	Canada AES Buoy 06	48.53000	-86.95000	Yes
1016	Buoy	AES	EC	45137	Canada AES Buoy 07	45.54000	-81.01000	Yes
1017	Buoy	AES	EC	45139	Canada AES Buoy 09	43.26000	-79.54000	Yes
1018	Buoy	AES	EC	45142	Canada AES Buoy 10	42.74000	-79.29000	Yes
1019	Buoy	AES	EC	45143	Canada AES Buoy 11	44.94000	-80.63000	Yes
1020	Buoy	AES	EC	45147	Canada AES Buoy	42.43000	-82.68000	Yes
1021	Buoy	AES	EC	45149	Canada AES Buoy	43.54000	-82.07000	Yes
1022	Buoy	AES	EC	45151	Canada AES Buoy 14	44.50000	-79.37000	Yes
1023	Buoy	AES	EC	45152	Canada AES Buoy 13	46.23000	-79.72000	Yes
1024	Buoy	AES	EC	45154	Canada AES Buoy 12	46.05000	-82.64000	Yes
1025	Buoy	AES	EC	45159	Canada AES Buoy	43.77000	-78.98000	Yes
1259	Buoy	AES	EC	45134	Canada AES Buoy 04	42.40000	-80.90000	No
1262	Buoy	AES	EC	45153	Canada AES Buoy	43.40000	-79.40000	No
1263	Buoy	AES	EC	45160	Canada AES Buoy	43.40000	-79.60000	No
65	WaterLevel	CN-WaterSurvey	EC	02AB018	LAKE SUPERIOR AT THUNDER BAY	48.40967	-89.21731	Yes
66	WaterLevel	CN-WaterSurvey	EC	02BA004	LAKE SUPERIOR AT ROSSPORT	48.83372	-87.51956	Yes
67	WaterLevel	CN-WaterSurvey	EC	02BD004	LAKE SUPERIOR AT MICHIPICOTEN HARBOUR	47.96169	-84.89828	Yes
68	WaterLevel	CN-WaterSurvey	EC	02BF010	LAKE SUPERIOR AT GROS CAP	46.52914	-84.58628	Yes
69	WaterLevel	CN-WaterSurvey	EC	02BF011	ST. MARYS RIVER AT SAULT STE. MARIE (ABOV	46.51247	-84.36733	Yes
70	WaterLevel	CN-WaterSurvey	EC	02CA005	ST. MARYS RIVER AT SAULT STE. MARIE (BELO	46.51128	-84.34322	Yes
71	WaterLevel	CN-WaterSurvey	EC	02CA006	LAKE HURON AT THESSALON	46.25400	-83.55106	Yes
72	WaterLevel	CN-WaterSurvey	EC	02CG002	LAKE HURON AT LITTLE CURRENT	45.98153	-81.92653	Yes
73	WaterLevel	CN-WaterSurvey	EC	02EA014	LAKE HURON AT PARRY SOUND	45.33856	-80.03578	Yes
74	WaterLevel	CN-WaterSurvey	EC	02ED012	LAKE HURON AT COLLINGWOOD	44.50842	-80.22008	Yes
75	WaterLevel	CN-WaterSurvey	EC	02ED033	LAKE HURON AT MIDLAND	44.75278	-79.88806	Yes
76	WaterLevel	CN-WaterSurvey	EC	02FA003	LAKE HURON AT TOBERMORY	45.25681	-81.66297	Yes
77	WaterLevel	CN-WaterSurvey	EC	02FE012	LAKE HURON AT GODERICH	43.74539	-81.72781	Yes
78	WaterLevel	CN-WaterSurvey	EC	02GC027	LAKE ERIE AT PORT STANLEY	42.65906	-81.21344	Yes
79	WaterLevel	CN-WaterSurvey	EC	02GC028	LAKE ERIE AT PORT DOVER	42.78142	-80.20156	Yes
80	WaterLevel	CN-WaterSurvey	EC	02GF002	LAKE ERIE AT ERIEAU	42.26014	-81.91467	Yes
81	WaterLevel	CN-WaterSurvey	EC	02GG010	ST. CLAIR RIVER AT POINT EDWARD	42.99128	-82.42150	Yes
82	WaterLevel	CN-WaterSurvey	EC	02GG011	ST. CLAIR RIVER AT PORT LAMBTON	42.65728	-82.50708	Yes
83	WaterLevel	CN-WaterSurvey	EC	02GH005	LAKE ST. CLAIR AT BELLE RIVER	42.29617	-82.71086	Yes
84	WaterLevel	CN-WaterSurvey	EC	02GH008	DETROIT RIVER AT AMHERSTBURG	42.14419	-83.11381	Yes
85	WaterLevel	CN-WaterSurvey	EC	02GH009	LAKE ERIE AT BAR POINT	42.06172	-83.11486	Yes
86	WaterLevel	CN-WaterSurvey	EC	02GH010	LAKE ERIE AT KINGSVILLE	42.02686	-82.73492	Yes
87	WaterLevel	CN-WaterSurvey	EC	02HA017	LAKE ERIE AT PORT COLBORNE	42.87450	-79.25283	Yes
88	WaterLevel	CN-WaterSurvey	EC	02HA018	LAKE ONTARIO AT PORT WELLER	43.23689	-79.21967	Yes
89	WaterLevel	CN-WaterSurvey	EC	02HB017	LAKE ONTARIO AT BURLINGTON	43.29972	-79.79278	Yes
90	WaterLevel	CN-WaterSurvey	EC	02HC048	LAKE ONTARIO AT TORONTO	43.63978	-79.38028	Yes
91	WaterLevel	CN-WaterSurvey	EC	02HD015	LAKE ONTARIO AT COBOURG	43.95778	-78.16500	Yes
92	WaterLevel	CN-WaterSurvey	EC	02HM008	LAKE ONTARIO AT KINGSTON	44.21750	-76.51750	Yes
93	WaterLevel	CN-WaterSurvey	EC	02MB007	ST. LAWRENCE RIVER AT BROCKVILLE	44.58689	-75.68200	Yes
94	WaterLevel	CN-WaterSurvey	EC	02MB008	ST. LAWRENCE RIVER AT IROQUOIS ISLAND (A	44.82233	-75.32056	Yes
95	WaterLevel	CN-WaterSurvey	EC	02MC022	ST. LAWRENCE RIVER BELOW CORNWALL CAN	45.01472	-74.71150	Yes
96	WaterLevel	CN-WaterSurvey	EC	02MC023	ST. LAWRENCE RIVER AT SUMMERSTOWN	45.05997	-74.55419	Yes
55	WaterLevel	OTHR	INC	1	Huntley	42.96907	-78.93105	Yes
56	WaterLevel	OTHR	INC	2	Tonawanda Island	43.02375	-78.88605	Yes
57	WaterLevel	OTHR	INC	3	Fort Erie	42.88685	-78.92542	Yes
58	WaterLevel	OTHR	INC	4	Frenchman's Creek	42.94276	-78.92691	Yes
59	WaterLevel	OTHR	INC	5	Black Creek	42.98126	-79.02326	Yes
60	WaterLevel	OTHR	INC	6	Material Dock	43.06188	-79.04348	Yes
61	WaterLevel	OTHR	INC	7	Slater's Point	43.06048	-79.03215	Yes
62	WaterLevel	OTHR	INC	8	American Falls	43.08111	-79.06071	Yes
63	WaterLevel	OTHR	INC	9	LaSalle	43.07310	-78.98548	Yes
64	WaterLevel	OTHR	INC	10	Peace Bridge	42.90762	-78.90989	Yes
1012	Buoy	MTU	MTU	45023	MTU/UM5 L.SuperiorMI	47.28000	-88.61000	Yes
1313	AOS	NWS	NOAA	CGX	Meigs Field Chi IL	41.87000	-87.62000	No
1120	AOS	NWS	NOAA	ACB	Bellaire MI	44.99000	-85.20000	Yes
1121	AOS	NWS	NOAA	AKR	Akron Intl AP OH	41.04000	-81.46000	Yes
1122	AOS	NWS	NOAA	ANJ	Sault Ste. Marie MI	46.48000	-84.36000	Yes

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1123	AOS	NWS	NOAA	APN	Alpena MI	45.07000	-83.56000	Yes
1124	AOS	NWS	NOAA	ART	Watertown NY	43.99000	-76.03000	Yes
1125	AOS	NWS	NOAA	ASX	Ashland WI	46.55000	-90.92000	Yes
1126	AOS	NWS	NOAA	BAX	BAD AXE MI	43.78000	-82.99000	Yes
1127	AOS	NWS	NOAA	BEH	Benton Harbor MI	42.13000	-86.42000	Yes
1128	AOS	NWS	NOAA	BFW	Silver Bay MN	47.20000	-91.40000	Yes
1129	AOS	NWS	NOAA	BIV	Holland MI	42.75000	-86.10000	Yes
1130	AOS	NWS	NOAA	BJJ	Wooster AP OH	40.87000	-81.89000	Yes
1131	AOS	NWS	NOAA	BKL	Burke LakefrontAP OH	41.53000	-81.67000	Yes
1132	AOS	NWS	NOAA	BUF	Buffalo NY	42.94000	-78.74000	Yes
1133	AOS	NWS	NOAA	CGF	Cuyahoga Cnty AP OH	41.57000	-81.48000	Yes
1134	AOS	NWS	NOAA	CIU	Chippewa Intl MI	46.25000	-84.47000	Yes
1135	AOS	NWS	NOAA	CKC	Grand Marais AirP MN	47.84000	-90.36000	Yes
1136	AOS	NWS	NOAA	CLE	Cleveland OH	41.41000	-81.85000	Yes
1137	AOS	NWS	NOAA	CMX	Houghton MI	47.17000	-88.48000	Yes
1138	AOS	NWS	NOAA	COQ	Cloquet (AWOS) MN	46.70000	-92.50000	Yes
1139	AOS	NWS	NOAA	CVX	Charlevoix AP MI	45.30000	-85.28000	Yes
1140	AOS	NWS	NOAA	DET	Detroit City AP MI	42.41000	-83.01000	Yes
1141	AOS	NWS	NOAA	DKK	Dunkirk NY	42.49000	-79.28000	Yes
1142	AOS	NWS	NOAA	DLH	Duluth MN	46.84000	-92.23000	Yes
1143	AOS	NWS	NOAA	DRM	Drummond Is AP MI	46.01000	-83.74000	Yes
1144	AOS	NWS	NOAA	DTW	Detroit Metro AP MI	42.23000	-83.31000	Yes
1145	AOS	NWS	NOAA	DUH	Tol Suburban AP OH	41.71000	-83.65000	Yes
1146	AOS	NWS	NOAA	DYT	Duluth (Sky Hbr) MN	46.72000	-92.04000	Yes
1147	AOS	NWS	NOAA	ENW	Kenosha WI	42.59000	-87.94000	Yes
1148	AOS	NWS	NOAA	ERI	Erie PA	42.08000	-80.18000	Yes
1149	AOS	NWS	NOAA	ERY	Luce County AP MI	46.29000	-85.46000	Yes
1150	AOS	NWS	NOAA	ESC	Escanaba MI	45.75000	-87.03000	Yes
1151	AOS	NWS	NOAA	ETB	West Bend WI	43.42000	-88.13000	Yes
1152	AOS	NWS	NOAA	FKS	Frankfort Dow AP MI	44.63000	-86.20000	Yes
1153	AOS	NWS	NOAA	FZY	Fulton NY	43.35000	-76.39000	Yes
1154	AOS	NWS	NOAA	GKJ	Port Meadville PA	41.63000	-80.21000	Yes
1155	AOS	NWS	NOAA	GNA	Grand Marais MN	47.75000	-90.35000	Yes
1156	AOS	NWS	NOAA	GRB	Green Bay WI	44.48000	-88.14000	Yes
1157	AOS	NWS	NOAA	GYY	Gary IN	41.62000	-87.42000	Yes
1158	AOS	NWS	NOAA	HYX	H.W. Brown AirP MI	43.43000	-83.86000	Yes
1159	AOS	NWS	NOAA	HZY	Ashtabula (7G2) OH	41.78000	-80.70000	Yes
1160	AOS	NWS	NOAA	IAG	Niagara Falls NY	43.11000	-78.94000	Yes
1161	AOS	NWS	NOAA	ISQ	Manistique MI	45.97000	-86.17000	Yes
1162	AOS	NWS	NOAA	IWD	Ironwood MI	46.53000	-90.13000	Yes
1163	AOS	NWS	NOAA	JHW	Jamestown NY	42.15000	-79.27000	Yes
1164	AOS	NWS	NOAA	LDM	Ludington MI	43.97000	-86.40000	Yes
1165	AOS	NWS	NOAA	LPR	Elyria (22G) OH	41.35000	-82.18000	Yes
1166	AOS	NWS	NOAA	MBL	Manistee MI	44.27000	-86.25000	Yes
1167	AOS	NWS	NOAA	MBS	Saginaw AP MI	43.54000	-84.08000	Yes
1168	AOS	NWS	NOAA	MCD	Mackinac Island MI	45.87000	-84.64000	Yes
1169	AOS	NWS	NOAA	MDW	Midway AP Chi IL	41.78000	-87.76000	Yes
1170	AOS	NWS	NOAA	MGN	Harbor Springs AP MI	45.43000	-84.91000	Yes
1171	AOS	NWS	NOAA	MKE	Milwaukee WI	42.95000	-87.90000	Yes
1172	AOS	NWS	NOAA	MKG	Muskegon MI	43.17000	-86.24000	Yes
1173	AOS	NWS	NOAA	MNM	Menominee MI	45.13000	-87.63000	Yes
1174	AOS	NWS	NOAA	MQT	Marquette MI	46.53000	-87.55000	Yes
1175	AOS	NWS	NOAA	MTC	Mount Clemens MI	42.62000	-82.83000	Yes
1176	AOS	NWS	NOAA	MTW	Manitowoc WI	44.13000	-87.68000	Yes
1177	AOS	NWS	NOAA	MWC	Milwauk/Timmerman WI	43.12000	-88.03000	Yes
1178	AOS	NWS	NOAA	ONZ	Detroit/Grosse IleMI	42.10000	-83.16000	Yes
1179	AOS	NWS	NOAA	ORD	OHare Field Chi IL	41.98000	-87.92000	Yes
1180	AOS	NWS	NOAA	OSC	Oscoda MI	44.45000	-83.40000	Yes
1181	AOS	NWS	NOAA	P53	NWS Munising MI	46.42000	-86.65000	Yes
1182	AOS	NWS	NOAA	P58	Harbor Beach MI	44.02000	-82.80000	Yes
1183	AOS	NWS	NOAA	P59	Copper Harbor MI	47.47000	-87.88000	Yes
1184	AOS	NWS	NOAA	PHN	Port Huron MI	42.92000	-82.53000	Yes
1185	AOS	NWS	NOAA	PLN	Pellston MI	45.56000	-84.79000	Yes
1186	AOS	NWS	NOAA	PTK	Pontiac MI	42.66000	-83.41000	Yes

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1187	AOS	NWS	NOAA	PWK	Chicago/Wheeling IL	42.12000	-87.90000	Yes
1188	AOS	NWS	NOAA	PZQ	Presque Isle AP MI	45.41000	-83.81000	Yes
1189	AOS	NWS	NOAA	RAC	Racine WI	42.76000	-87.82000	Yes
1190	AOS	NWS	NOAA	ROC	Rochester NY	43.12000	-77.68000	Yes
1191	AOS	NWS	NOAA	SAW	Sawyer AP Gwinn MI	46.35000	-87.40000	Yes
1192	AOS	NWS	NOAA	SBM	Sheboygan WI	43.78000	-87.85000	Yes
1193	AOS	NWS	NOAA	SBN	South Bend IN	41.71000	-86.32000	Yes
1194	AOS	NWS	NOAA	SJX	Beaver Island AP MI	45.69000	-85.57000	Yes
1195	AOS	NWS	NOAA	SLH	Cheboygan AP MI	45.65000	-84.52000	Yes
1196	AOS	NWS	NOAA	SUE	Sturgeon Bay WI	44.85000	-87.42000	Yes
1197	AOS	NWS	NOAA	SUW	Richard Bong AirP WI	46.69000	-92.09000	Yes
1198	AOS	NWS	NOAA	SYR	Syracuse NY	43.11000	-76.10000	Yes
1199	AOS	NWS	NOAA	TDZ	Toledo MetcalfFld OH	41.56000	-83.49000	Yes
1200	AOS	NWS	NOAA	TOL	Toledo OH	41.59000	-83.80000	Yes
1201	AOS	NWS	NOAA	TTF	Monroe MI	41.94000	-83.43000	Yes
1202	AOS	NWS	NOAA	TTR	Tobermory ONT	45.22000	-81.64000	Yes
1203	AOS	NWS	NOAA	TVC	Traverse City MI	44.74000	-85.57000	Yes
1204	AOS	NWS	NOAA	TWM	Two Harbors MN	47.05000	-91.75000	Yes
1205	AOS	NWS	NOAA	UES	Waukesha Cnty WI	43.04000	-88.24000	Yes
1206	AOS	NWS	NOAA	UGN	Chicago/Waukegan IL	42.42000	-87.87000	Yes
1207	AOS	NWS	NOAA	VPZ	Valparaiso IN	41.45000	-87.00000	Yes
1208	AOS	NWS	NOAA	WAJ	Rondeau ONT	42.25000	-81.90000	Yes
1209	AOS	NWS	NOAA	WBE	Killarney ONT	45.97000	-81.48000	Yes
1210	AOS	NWS	NOAA	WCI	Caribou Island ONT	47.33000	-85.83000	Yes
1211	AOS	NWS	NOAA	WCJ	Pukaskwa ONT	48.60000	-86.30000	Yes
1212	AOS	NWS	NOAA	WCO	Collingwood ONT	44.50000	-80.22000	Yes
1213	AOS	NWS	NOAA	WEC	Welcome Island ONT	48.37000	-89.12000	Yes
1214	AOS	NWS	NOAA	WGD	Goderich ONT	43.77000	-81.72000	Yes
1215	AOS	NWS	NOAA	WKK	Little Flatland ONT	49.69000	-88.31000	Yes
1216	AOS	NWS	NOAA	WMZ	Western Island ONT	45.03000	-80.37000	Yes
1217	AOS	NWS	NOAA	WNB	Southeast Shoal ONT	41.83000	-82.47000	Yes
1218	AOS	NWS	NOAA	WNC	Cobourg ONT	43.95000	-78.17000	Yes
1219	AOS	NWS	NOAA	WNL	Great Duck Is ONT	45.63000	-82.97000	Yes
1220	AOS	NWS	NOAA	WNZ	Nagagami ONT	49.75000	-84.17000	Yes
1221	AOS	NWS	NOAA	WPC	Port Colbourne ONT	42.87000	-79.25000	Yes
1222	AOS	NWS	NOAA	WPS	Long Point ONT	42.57000	-80.05000	Yes
1223	AOS	NWS	NOAA	WQP	Point Petre ONT	43.83000	-77.15000	Yes
1224	AOS	NWS	NOAA	WWB	Burlington Pier ONT	43.30000	-79.80000	Yes
1225	AOS	NWS	NOAA	WWX	Cove Island ONT	45.33000	-81.73000	Yes
1226	AOS	NWS	NOAA	WWZ	Port Weller ONT	43.25000	-79.22000	Yes
1227	AOS	NWS	NOAA	XCA	Cameron Falls ONT	49.15000	-88.35000	Yes
1228	AOS	NWS	NOAA	XDI	Delhi CS ONT	42.87000	-80.55000	Yes
1229	AOS	NWS	NOAA	XHA	Harrow ONT	42.03000	-82.90000	Yes
1230	AOS	NWS	NOAA	XHM	Hamilton ONT	43.28000	-79.92000	Yes
1231	AOS	NWS	NOAA	XPC	Parry Sound ONT	45.33000	-80.03000	Yes
1232	AOS	NWS	NOAA	XPT	Point Pelee ONT	41.95000	-82.51000	Yes
1233	AOS	NWS	NOAA	XTO	Toronto Cty AP ONT	43.67000	-79.40000	Yes
1234	AOS	NWS	NOAA	YAM	Sault Ste. Marie ONT	46.48000	-84.50000	Yes
1235	AOS	NWS	NOAA	YEL	Elliot Lake AP ONT	46.33000	-82.56000	Yes
1236	AOS	NWS	NOAA	YGK	Kingston ONT	44.22000	-76.60000	Yes
1237	AOS	NWS	NOAA	YGQ	Geraldton ONT	49.78000	-86.93000	Yes
1238	AOS	NWS	NOAA	YHM	Hamilton ONT	43.17000	-79.93000	Yes
1239	AOS	NWS	NOAA	YIP	Detroit WillowRun MI	42.24000	-83.53000	Yes
1240	AOS	NWS	NOAA	YKZ	buttonville ONT	43.87000	-79.37000	Yes
1241	AOS	NWS	NOAA	YLD	Chapleau ONT	47.82000	-83.35000	Yes
1242	AOS	NWS	NOAA	YNG	Youngstown OH	41.25000	-80.67000	Yes
1243	AOS	NWS	NOAA	YPQ	Peterborough ONT	44.23000	-78.37000	Yes
1244	AOS	NWS	NOAA	YQA	Muskoka ONT	44.97000	-79.30000	Yes
1245	AOS	NWS	NOAA	YQG	Windsor ONT	42.27000	-82.97000	Yes
1246	AOS	NWS	NOAA	YQT	Thunder Bay ONT	48.37000	-89.32000	Yes
1247	AOS	NWS	NOAA	YSB	Sudbury ONT	46.62000	-80.80000	Yes
1248	AOS	NWS	NOAA	YSN	St. Catherines ONT	43.20000	-79.17000	Yes
1249	AOS	NWS	NOAA	YSP	Marathon ONT	48.75000	-86.35000	Yes
1250	AOS	NWS	NOAA	YTR	Trenton ONT	44.12000	-77.53000	Yes

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1251	AOS	NWS	NOAA	YTZ	Toronto Island ONT	43.63000	-79.40000	Yes
1252	AOS	NWS	NOAA	YVV	Wiarton ONT	44.75000	-81.10000	Yes
1253	AOS	NWS	NOAA	YXU	London ONT	43.03000	-81.15000	Yes
1254	AOS	NWS	NOAA	YXZ	Wawa ONT	47.97000	-84.78000	Yes
1255	AOS	NWS	NOAA	YYZ	Toronto Intl AP ONT	43.67000	-79.63000	Yes
1256	AOS	NWS	NOAA	YZE	Gore Bay ONT	45.88000	-82.57000	Yes
1257	AOS	NWS	NOAA	YZR	Sarnia ONT	43.00000	-82.32000	Yes
1258	AOS	NWS	NOAA	ZTB	Thunder Bay ONT	48.37000	-89.27000	Yes
916	Buoy	GLERL	NOAA	GHNB	Grand Haven North Buoy	43.07362	-86.26338	Yes
918	Buoy	GLERL	NOAA	GHSB	Grand Haven South Buoy	43.03302	-86.24958	Yes
919	Buoy	GLERL	NOAA	MUSKB	Muskegon Buoy	43.18817	-86.34400	Yes
920	Buoy	GLERL	NOAA	APNTB	Alpena - Thunder Bay Buoy	44.98410	-83.26867	Yes
921	Buoy	GLERL	NOAA	SBB	Saginaw Bay Buoy	43.98817	-83.59898	Yes
922	Buoy	GLERL	NOAA	SBM1	Saginaw Bay Marker #1	43.80577	-83.71873	Yes
923	Buoy	GLERL	NOAA	SBM2	Toledo Channel Marker #2	41.82555	-83.19362	Yes
925	Buoy	GLERL	NOAA	WLEB	West Lake Erie Buoy	41.75392	-83.23142	Yes
926	Buoy	GLERL	NOAA	CLVBN	Cleveland North Buoy	41.81393	-81.69882	Yes
927	Buoy	GLERL	NOAA	CLVBC	Cleveland Central Buoy	41.73352	-81.69840	Yes
1000	Buoy	NDBC	NOAA	45001	NDBC Data Buoy 01	48.06000	-87.78000	Yes
1001	Buoy	NDBC	NOAA	45002	NDBC Data Buoy 02	45.34000	-86.41000	Yes
1002	Buoy	NDBC	NOAA	45003	NDBC Data Buoy 03	45.35000	-82.84000	Yes
1003	Buoy	NDBC	NOAA	45004	NDBC Data Buoy 04	47.58000	-86.59000	Yes
1004	Buoy	NDBC	NOAA	45005	NDBC Data Buoy 05	41.68000	-82.40000	Yes
1005	Buoy	NDBC	NOAA	45006	NDBC Data Buoy 06	47.33000	-89.79000	Yes
1006	Buoy	NDBC	NOAA	45007	NDBC Data Buoy 07	42.70000	-86.97000	Yes
1007	Buoy	NDBC	NOAA	45008	NDBC Data Buoy 08	44.28000	-82.42000	Yes
1008	Buoy	NDBC	NOAA	45012	NDBC Data Buoy 12	43.62000	-77.41000	Yes
1260	Buoy	NDBC	NOAA	45010	NDBC Data Buoy 10	43.00000	-87.80000	No
1261	Buoy	NDBC	NOAA	45011	NDBC Data Buoy 11	43.00000	-86.30000	No
1029	CMAN	GLERL	NOAA	APNM4	GLERL Alpena MI	45.06000	-83.42000	Yes
1036	CMAN	GLERL	NOAA	CHII2	GLERL Chicago IL	41.92000	-87.57000	Yes
1059	CMAN	GLERL	NOAA	KNSW3	GLERL Kenosha WI	42.59000	-87.81000	Yes
1068	CMAN	GLERL	NOAA	MCYI3	GLERL MichiganCityIN	41.73000	-86.91000	Yes
1070	CMAN	GLERL	NOAA	MKGM4	GLERL Muskegon MI	43.23000	-86.34000	Yes
1071	CMAN	GLERL	NOAA	MLWW3	GLERL Milwaukee WI	43.05000	-87.88000	Yes
1102	CMAN	GLERL	NOAA	SVNM4	GLERL South Haven MI	42.40000	-86.29000	Yes
1107	CMAN	GLERL	NOAA	THLO1	GLERL Toledo Lt 2 OH	41.83000	-83.19000	Yes
1264	CMAN	GLERL	NOAA	SAUM4	GLERL Saugatuck MI	42.68000	-86.22000	No
1267	CMAN	GLERL	NOAA	ALNM4	GLERL Alpena MI	45.05000	-83.45000	No
917	CMAN	GLERL	NOAA	GHP	Grand Haven Pier	43.05707	-86.25878	Yes
924	CMAN	GLERL	NOAA	TOLHL	Toledo Harbor Light	41.76198	-83.32895	Yes
1026	CMAN	NDBC	NOAA	ABAN6	NDBC Alexandria Bay	44.33000	-75.93000	Yes
1041	CMAN	NDBC	NOAA	DBLN6	NDBC Dunkirk NY	42.49000	-79.35000	Yes
1063	CMAN	NDBC	NOAA	LSCM4	NDBC Lake St ClairMI	42.47000	-82.76000	Yes
1082	CMAN	NDBC	NOAA	PILM4	NDBC PassageIslandMI	48.22000	-88.37000	Yes
1092	CMAN	NDBC	NOAA	ROAM4	NDBC Rock of Ages MI	47.87000	-89.31000	Yes
1094	CMAN	NDBC	NOAA	SBIO1	NDBC South Bass I OH	41.63000	-82.84000	Yes
1096	CMAN	NDBC	NOAA	SGNW3	NDBC Sheboygan WI	43.75000	-87.69000	Yes
1100	CMAN	NDBC	NOAA	STDM4	NDBC Stannard RockMI	47.18000	-87.23000	Yes
1101	CMAN	NDBC	NOAA	SUPN6	NDBC SuperiorShoals	44.47000	-75.80000	Yes
1106	CMAN	NDBC	NOAA	THIN6	NDBC ThousandIslands	44.30000	-75.98000	Yes
1265	CMAN	NDBC	NOAA	GLLN6	NDBCGalloo Island NY	43.89000	-76.45000	No
1080	CMAN	NERRS	NOAA	OWXO1	NERRS OldWomanCrk OH	41.38000	-82.51000	Yes
1028	CMAN	NOS	NOAA	ALXN6	NOS Alexandria Bay	44.33000	-75.93000	Yes
1033	CMAN	NOS	NOAA	BUFN6	NOS Buffalo NY	42.88000	-78.89000	Yes
1038	CMAN	NOS	NOAA	CMTI2	NOS Calumet Harb IL	41.73000	-87.54000	Yes
1039	CMAN	NOS	NOAA	CNDO1	NOS Cleveland OH	41.54000	-81.64000	Yes
1042	CMAN	NOS	NOAA	DISW3	NDBC Devils IslandWI	47.08000	-90.73000	Yes
1043	CMAN	NOS	NOAA	DTLM4	NOS De Tour Vill MI	45.99000	-83.90000	Yes
1044	CMAN	NOS	NOAA	DULM5	NOS Duluth MN	46.78000	-92.09000	Yes
1045	CMAN	NOS	NOAA	FAIO1	NOS Fairport OH	41.76000	-81.28000	Yes
1047	CMAN	NOS	NOAA	FTGM4	NOS Fort Gratiot MI	43.01000	-82.42000	Yes
1049	CMAN	NOS	NOAA	GDMM5	NOS Grand Marais MN	47.75000	-90.34000	Yes
1057	CMAN	NOS	NOAA	HLNM4	NOS Holland MI	42.77000	-86.20000	Yes
1058	CMAN	NOS	NOAA	HRBM4	NOS Harbor Beach MI	43.85000	-82.64000	Yes

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1060	CMAN	NOS	NOAA	KWNW3	NOS Kewaunee WI	44.28000	-87.50000	Yes
1061	CMAN	NOS	NOAA	LDTM4	NOS Ludington MI	43.95000	-86.44000	Yes
1062	CMAN	NOS	NOAA	LPNM4	NOS Alpena MI	45.06000	-83.43000	Yes
1064	CMAN	NOS	NOAA	LTRM4	NOS Little Rapids MI	46.49000	-84.30000	Yes
1065	CMAN	NOS	NOAA	MACM4	NOS Mackinaw City MI	45.78000	-84.72000	Yes
1066	CMAN	NOS	NOAA	MBRM4	NOS Mouth Black R MI	42.97000	-82.42000	Yes
1067	CMAN	NOS	NOAA	MCGM4	NOS Marquette CG MI	46.55000	-87.38000	Yes
1072	CMAN	NOS	NOAA	MNMM4	NOS Menominee MI	45.10000	-87.60000	Yes
1073	CMAN	NOS	NOAA	MRHO1	NOS Marblehead OH	41.55000	-82.73000	Yes
1075	CMAN	NOS	NOAA	NIAN6	NOS Niagara IntakeNY	43.08000	-79.01000	Yes
1078	CMAN	NOS	NOAA	OSGN6	NOS Oswego NY	43.46000	-76.51000	Yes
1084	CMAN	NOS	NOAA	PNLM4	NOS Port Inland MI	45.97000	-85.87000	Yes
1087	CMAN	NOS	NOAA	PSTN6	NOS Sturgeon Pt NY	42.69000	-79.05000	Yes
1088	CMAN	NOS	NOAA	PTIM4	NOS PointIroquois MI	46.49000	-84.63000	Yes
1090	CMAN	NOS	NOAA	RCKM4	NOS Rock Cut MI	46.27000	-84.19000	Yes
1091	CMAN	NOS	NOAA	RCRN6	NOS Rochester NY	43.27000	-77.63000	Yes
1103	CMAN	NOS	NOAA	SWPM4	NOS S.W. Pier MI	46.50000	-84.37000	Yes
1108	CMAN	NOS	NOAA	THRO1	NOS Toledo OH	41.69000	-83.47000	Yes
1111	CMAN	NOS	NOAA	WNEM4	NOS West Neebish MI	46.28000	-84.21000	Yes
1266	CMAN	NOS	NOAA	NY034	NOS Ogdensburg NY	44.70000	-75.49000	No
1027	CMAN	NWS	NOAA	AGMW3	NWS Algoma Marina WI	44.61000	-87.43000	Yes
1030	CMAN	NWS	NOAA	BHRI3	NWS Burns Harbor IN	41.65000	-87.15000	Yes
1031	CMAN	NWS	NOAA	BIGM4	NWS Big Bay MI	46.83000	-87.73000	Yes
1032	CMAN	NWS	NOAA	BSBM4	NWS Big Sable Pt MI	44.05000	-86.51000	Yes
1034	CMAN	NWS	NOAA	CBLO1	NWS Conneaut Lt OH	41.98000	-80.56000	Yes
1035	CMAN	NWS	NOAA	CBRW3	NWS ChambersIslandWI	45.20000	-87.36000	Yes
1037	CMAN	NWS	NOAA	CLSM4	NWS St.ClairShoresMI	42.47000	-82.88000	Yes
1040	CMAN	NWS	NOAA	CYGM4	Cheboygan MI	45.65000	-84.47000	Yes
1046	CMAN	NWS	NOAA	FPTM4	NWS Fairport MI	45.62000	-86.66000	Yes
1048	CMAN	NWS	NOAA	GBLW3	NWS Green Bay Lt WI	44.66000	-87.90000	Yes
1050	CMAN	NWS	NOAA	GELO1	NWS GenevaOnThLakeOH	41.86000	-80.97000	Yes
1051	CMAN	NWS	NOAA	GRMM4	NWS Grand Marais MI	46.68000	-85.97000	Yes
1052	CMAN	NWS	NOAA	GSLM4	NWS GravellyShoalsMI	44.02000	-83.54000	Yes
1054	CMAN	NWS	NOAA	GTLM4	NWS GrndTraverseLtMI	45.21000	-85.55000	Yes
1055	CMAN	NWS	NOAA	GTRM4	NWS SupGrndTravBayMI	47.18000	-88.24000	Yes
1056	CMAN	NWS	NOAA	HHLO1	NWS Huron Light OH	41.40000	-82.55000	Yes
1069	CMAN	NWS	NOAA	MEEM4	NWS Manistee Hbr MI	44.25000	-86.35000	Yes
1074	CMAN	NWS	NOAA	NABM4	NWS Naubinway MI	46.09000	-85.44000	Yes
1076	CMAN	NWS	NOAA	NPDW3	NWS Northport PierWI	45.29000	-86.98000	Yes
1077	CMAN	NWS	NOAA	OLCN6	NWS Olcott Harbor NY	43.34000	-78.72000	Yes
1079	CMAN	NWS	NOAA	OTNM4	NWS Ontonagon MI	46.87000	-89.33000	Yes
1081	CMAN	NWS	NOAA	PCLM4	NWS Portage Canal MI	47.28000	-88.53000	Yes
1083	CMAN	NWS	NOAA	PNGW3	NWS Port Wing WI	46.79000	-91.39000	Yes
1085	CMAN	NWS	NOAA	PRIM4	Presque Isle MI	45.36000	-83.49000	Yes
1086	CMAN	NWS	NOAA	PSCM4	NWS Port Sanilac MI	43.42000	-82.54000	Yes
1089	CMAN	NWS	NOAA	PWAW3	NWS PortWashingtonWI	43.39000	-87.87000	Yes
1093	CMAN	NWS	NOAA	RPRN6	NWS Rochester NY	43.26000	-77.59000	Yes
1095	CMAN	NWS	NOAA	SBLM4	NWS SaginawBayLt1 MI	43.81000	-83.72000	Yes
1097	CMAN	NWS	NOAA	SJOM4	NWS St. Joseph MI	42.10000	-86.49000	Yes
1098	CMAN	NWS	NOAA	SLVM5	NWS Silver Bay MN	47.27000	-91.25000	Yes
1099	CMAN	NWS	NOAA	SPTM4	Sturgeon Point MI	44.71000	-83.27000	Yes
1104	CMAN	NWS	NOAA	SXHW3	NWS Saxon Harbor WI	46.56000	-90.44000	Yes
1105	CMAN	NWS	NOAA	TAWM4	TawasPoint MI	44.26000	-83.44000	Yes
1109	CMAN	NWS	NOAA	WFPM4	Whitefish Point MI	46.76000	-84.97000	Yes
1110	CMAN	NWS	NOAA	WHRI2	NWS Waukegan Hrbr IL	42.36000	-87.81000	Yes
1112	CMAN	NWS	NOAA	YGNN6	NWS Niagara CG NY	43.26000	-79.06000	Yes
1	WaterLevel	NOS	NOAA	8311030	Ogdensburg, NY	44.70167	-75.49333	Yes
2	WaterLevel	NOS	NOAA	9014070	Algonac, MI	42.62000	-82.52667	Yes
3	WaterLevel	NOS	NOAA	9014087	Dry Dock, MI	42.94500	-82.44333	Yes
4	WaterLevel	NOS	NOAA	9014096	Dunn Paper, MI	43.00167	-82.42167	Yes
5	WaterLevel	NOS	NOAA	9034052	St Clair Shores, MI	42.47167	-82.87833	Yes
6	WaterLevel	NOS	NOAA	9044030	Wyandotte, MI	42.20167	-83.14667	Yes
7	WaterLevel	NOS	NOAA	9044049	Windmill Point, MI	42.35667	-82.93000	Yes
8	WaterLevel	NOS	NOAA	9052030	Oswego, NY	43.46333	-76.51167	Yes

2. OVERVIEW

An ocean data network is an infrastructure of data, systems, services, and tools that allow a variety of users including the public, coastal managers, and research scientists to access "live" and archived data related to coastal and ocean management. This may include maps, observations, and model data. The goal of the data management and communications (or cyberinfrastructure) component of an integrated ocean observing system (IOOS) is to fully integrate these disparate data feeds to provide data, information and analysis to the broad range of users.

Numerous reports have been prepared on this topic in recent years that suggest that the societal benefits of ocean observing are several hundreds of millions of dollars per year and recommend

"Cost efficient and effective means of communicating the information derived from the ocean observations to users in a timely manner", and that users should be able to "effectively incorporate the information into their decisions".

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
9	WaterLevel	NOS	NOAA	9052076	Olcott, NY	43.33833	-78.72667	Yes
10	WaterLevel	NOS	NOAA	9063009	American Falls, NY	43.08000	-79.06000	Yes
11	WaterLevel	NOS	NOAA	9063020	Buffalo, NY	42.87667	-78.89000	Yes
12	WaterLevel	NOS	NOAA	9063038	Erie, PA	42.15333	-80.09167	Yes
13	WaterLevel	NOS	NOAA	9063063	Cleveland, OH	41.54000	-81.63500	Yes
14	WaterLevel	NOS	NOAA	9063085	Toledo, OH	41.69333	-83.47167	Yes
15	WaterLevel	NOS	NOAA	9075002	Lakeport, MI	43.14000	-82.49333	Yes
16	WaterLevel	NOS	NOAA	9075035	Essexville, MI	43.64000	-83.84667	Yes
17	WaterLevel	NOS	NOAA	9075080	Mackinaw City, MI	45.77667	-84.72500	Yes
18	WaterLevel	NOS	NOAA	9076024	Rock Cut, MI	46.26333	-84.19000	Yes
19	WaterLevel	NOS	NOAA	9076032	Little Rapids, MI	46.48333	-84.30000	Yes
20	WaterLevel	NOS	NOAA	9076060	U.S. Slip, MI	46.50000	-84.34000	Yes
21	WaterLevel	NOS	NOAA	9087023	Ludington, MI	43.94667	-86.44167	Yes
22	WaterLevel	NOS	NOAA	9087044	Calumet Harbor, IL	41.72833	-87.53833	Yes
23	WaterLevel	NOS	NOAA	9087068	Kewaunee, WI	44.46333	-87.50000	Yes
24	WaterLevel	NOS	NOAA	9087079	Green Bay, WI	44.54000	-88.00667	Yes
25	WaterLevel	NOS	NOAA	9087096	Port Inland, MI	45.96833	-85.87000	Yes
26	WaterLevel	NOS	NOAA	9099018	Marquette C.G., MI	46.54500	-87.37833	Yes
27	WaterLevel	NOS	NOAA	9099064	Duluth, MN	46.77500	-92.09167	Yes
28	WaterLevel	NOS	NOAA	8311062	Alexandria Bay, NY	44.33000	-75.93333	Yes
29	WaterLevel	NOS	NOAA	9014080	St Clair State Police, MI	42.81167	-82.48500	Yes
30	WaterLevel	NOS	NOAA	9014090	Mouth of the Black River, MI	42.97333	-82.42000	Yes
31	WaterLevel	NOS	NOAA	9014098	Fort Gratiot, MI	43.00667	-82.42167	Yes
32	WaterLevel	NOS	NOAA	9044020	Gibraltar, MI	42.09000	-83.18500	Yes
33	WaterLevel	NOS	NOAA	9044036	Fort Wayne, MI	42.29833	-83.09167	Yes
34	WaterLevel	NOS	NOAA	9052000	Cape Vincent, NY	44.13000	-76.33167	Yes
35	WaterLevel	NOS	NOAA	9052058	Rochester, NY	43.26833	-77.62500	Yes
36	WaterLevel	NOS	NOAA	9063007	Ashland Ave., NY	43.10000	-79.06000	Yes
37	WaterLevel	NOS	NOAA	9063012	Niagara Intake, NY	43.07667	-79.01333	Yes
38	WaterLevel	NOS	NOAA	9063028	Sturgeon Point, NY	42.69000	-79.04667	Yes
39	WaterLevel	NOS	NOAA	9063053	Fairport, OH	41.75833	-81.28000	Yes
40	WaterLevel	NOS	NOAA	9063079	Marblehead, OH	41.54333	-82.73000	Yes
41	WaterLevel	NOS	NOAA	9063090	Fermi Power Plant, MI	41.96000	-83.25667	Yes
42	WaterLevel	NOS	NOAA	9075014	Harbor Beach, MI	43.84500	-82.64167	Yes
43	WaterLevel	NOS	NOAA	9075065	Alpena, MI	45.06167	-83.42833	Yes
44	WaterLevel	NOS	NOAA	9075099	De Tour Village, MI	45.99167	-83.89667	Yes
45	WaterLevel	NOS	NOAA	9076027	West Neebish Island, MI	46.28333	-84.20833	Yes
46	WaterLevel	NOS	NOAA	9076033	Little Rapids, MI	46.48500	-84.30167	Yes
47	WaterLevel	NOS	NOAA	9076070	S.W. Pier, MI	46.50000	-84.37167	Yes
48	WaterLevel	NOS	NOAA	9087031	Holland, MI	42.76667	-86.20000	Yes
49	WaterLevel	NOS	NOAA	9087057	Milwaukee, WI	43.00167	-87.88667	Yes
50	WaterLevel	NOS	NOAA	9087072	Sturgeon Bay Canal, WI	44.79500	-87.31333	Yes
51	WaterLevel	NOS	NOAA	9087088	Menominee, MI	45.09500	-87.59000	Yes
52	WaterLevel	NOS	NOAA	9099004	Point Iroquois, MI	46.48333	-84.63000	Yes
53	WaterLevel	NOS	NOAA	9099044	Ontonagon, MI	46.87333	-89.32333	Yes
54	WaterLevel	NOS	NOAA	9099090	Grand Marais, MN	47.74667	-90.34000	Yes
1115	CMAN	OTHR	PRVT	CMPO1	Perry OH	41.76000	-81.14000	Yes
1116	CMAN	OTHR	PRVT	LOR	Lorain Light OH	41.48000	-82.20000	Yes
1117	CMAN	OTHR	PRVT	NREP1	Northeast PA	42.27000	-79.76000	Yes
1118	CMAN	OTHR	PRVT	TAWAS	Tawas Point MI	44.26000	-83.44000	Yes
1119	CMAN	OTHR	PRVT	WCRP1	Walnut Creek PA	42.08000	-80.24000	Yes
1300	PORT	OTHR	PRVT	CLTO1	Cleveland Edgewtr Pk	41.50000	-81.73000	No
1301	PORT	OTHR	PRVT	LIX	Cleve W Pierhd Lt OH	41.50000	-81.73000	No
1302	PORT	OTHR	PRVT	FRH	Fairport Harb Light	41.76000	-81.28000	No
1303	PORT	OTHR	PRVT	PERRY	Perry OH	41.76000	-81.14000	No
1304	PORT	OTHR	PRVT	70G	Ashtabula Light OH	41.91000	-80.80000	No
1305	PORT	OTHR	PRVT	ASH	Ashtabula Light OH	41.91000	-80.80000	No
1306	PORT	OTHR	PRVT	EOIP1	Presque Isle Light	42.15000	-80.10000	No
1307	PORT	OTHR	PRVT	GSRW3	Gills Rock WI	45.30000	-86.98000	No
1308	PORT	OTHR	PRVT	DTRM4	DeTour Passage MI	46.00000	-83.92000	No
1309	PORT	OTHR	PRVT	P55	DeTour Passage MI	46.00000	-83.92000	No
1310	PORT	OTHR	PRVT	27Y	Grand Marais MI	46.68000	-85.98000	No
1311	PORT	OTHR	PRVT	26Y	Whitefish Point MI	46.76000	-84.96000	No
1312	PORT	OTHR	PRVT	ONTM4	Ontonagon MI	46.83000	-89.33000	No
1009	Buoy	UMICH	UMICH	45020	UM1 GrandTravBay MI	44.79000	-85.60000	Yes
1010	Buoy	UMICH	UMICH	45021	UM3 Traverse Bay MI	45.05000	-85.49000	Yes
1011	Buoy	UMICH	UMICH	45022	UM4 LittleTravBay MI	45.40000	-85.09000	Yes

ID	Program	Division	Agency	StationID	Name	Lat	Long	Active
1053	CMAN	UMICH	UMICH	GTBM4	UM2 GrandTravBay MI	44.77000	-85.61000	Yes
1113	CMAN	USCG	USCG	20G	Ashtabula CG OH	41.90000	-80.80000	Yes
1114	CMAN	USCG	USCG	29G	Fairport Harbor CG	41.76000	-81.28000	Yes
1268	PORT	USCG	USCG	27G	Lorain CG OH	41.47000	-82.18000	No
1269	PORT	USCG	USCG	21G	Marblehead CG OH	41.54000	-82.73000	No
1270	PORT	USCG	USCG	24G	Toledo CG OH	41.69000	-83.47000	No
1271	PORT	USCG	USCG	18C	Michigan City CG IN	41.72000	-86.90000	No
1272	PORT	USCG	USCG	63G	Calumet Harbor CG IL	41.72000	-87.53000	No
1273	PORT	USCG	USCG	62G	Wilmette CG IL	42.08000	-87.68000	No
1274	PORT	USCG	USCG	20C	St. Joseph CG MI	42.12000	-86.48000	No
1275	PORT	USCG	USCG	25G	Erie CG OH	42.15000	-80.08000	No
1276	PORT	USCG	USCG	31G	Belle Isle CG MI	42.34000	-82.96000	No
1277	PORT	USCG	USCG	41Y	StClair Shores CG MI	42.47000	-82.88000	No
1278	PORT	USCG	USCG	16C	Kenosha CG WI	42.58000	-87.75000	No
1279	PORT	USCG	USCG	19G	Buffalo CG NY	42.88000	-78.88000	No
1280	PORT	USCG	USCG	33G	Port Huron CG MI	43.00000	-82.42000	No
1281	PORT	USCG	USCG	15C	Milwaukee CG WI	43.02000	-87.95000	No
1282	PORT	USCG	USCG	19C	Muskegon CG MI	43.23000	-86.33000	No
1283	PORT	USCG	USCG	13G	Niagara CG NY	43.26000	-79.04000	No
1284	PORT	USCG	USCG	26G	Rochester CG NY	43.26000	-77.60000	No
1285	PORT	USCG	USCG	28G	Oswego CG NY	43.46000	-76.52000	No
1286	PORT	USCG	USCG	30G	Saginaw River CG MI	43.63000	-83.84000	No
1287	PORT	USCG	USCG	21C	Sheboygan CG WI	43.75000	-87.70000	No
1288	PORT	USCG	USCG	17C	Ludington CG MI	43.95000	-86.40000	No
1289	PORT	USCG	USCG	C58	Two Rivers CG WI	44.15000	-87.56000	No
1290	PORT	USCG	USCG	39Y	Tawas Point CG MI	44.26000	-83.44000	No
1291	PORT	USCG	USCG	6B3	Alexandria Bay CG NY	44.33000	-75.95000	No
1292	PORT	USCG	USCG	14C	Frankfort CG MI	44.70000	-86.25000	No
1293	PORT	USCG	USCG	0Y2	Sturgeon Bay CG WI	44.80000	-87.31000	No
1294	PORT	USCG	USCG	Y09	Charlevoix CG MI	45.32000	-85.27000	No
1295	PORT	USCG	USCG	38Y	St. Ignace CG MI	45.86000	-84.70000	No
1296	PORT	USCG	USCG	44Y	Sault Ste. Marie CG	46.50000	-84.33000	No
1297	PORT	USCG	USCG	34Y	Marquette CG MI	46.55000	-87.38000	No
1298	PORT	USCG	USCG	30Y	Duluth CG MN	46.77000	-92.08000	No
1299	PORT	USCG	USCG	32Y	Portage CG MI	47.23000	-88.63000	No

Table A-2 Inventory of Real-Time Stations (USGS Watershed Gages)								
ID	**Program**	**Division**	**Agency**	**Station**	**Name**	**LAT**	**LONG**	**Active**
102	NWIS	Water	USGS	04010500	PIGEON RIVER AT MIDDLE FALLS NR GRAND PORTAGE MN	48.01211	-89.61620	Yes
107	NWIS	Water	USGS	04024000	ST. LOUIS RIVER AT SCANLON, MN	46.70328	-92.41880	Yes
120	NWIS	Water	USGS	04122200	WHITE RIVER NEAR WHITEHALL, MI	43.46418	-86.23257	Yes
133	NWIS	Water	USGS	04024430	NEMADJI RIVER NEAR SOUTH SUPERIOR, WI	46.63327	-92.09408	Yes
135	NWIS	Water	USGS	04027000	BAD RIVER NEAR ODANAH, WI	46.48661	-90.69630	Yes
136	NWIS	Water	USGS	04027500	WHITE RIVER NEAR ASHLAND, WI	46.49828	-90.90325	Yes
145	NWIS	Water	USGS	04059000	ESCANABA RIVER AT CORNELL, MI	45.90857	-87.21375	Yes
150	NWIS	Water	USGS	04069500	PESHTIGO RIVER AT PESHTIGO, WI	45.04749	-87.74455	Yes
154	NWIS	Water	USGS	04086000	SHEBOYGAN RIVER AT SHEBOYGAN, WI	43.74166	-87.75398	Yes
156	NWIS	Water	USGS	04087000	MILWAUKEE RIVER AT MILWAUKEE, WI	43.10001	-87.90897	Yes
169	NWIS	Water	USGS	04102500	PAW PAW RIVER AT RIVERSIDE, MI	42.18643	-86.36891	Yes
187	NWIS	Water	USGS	04122500	PERE MARQUETTE RIVER AT SCOTTVILLE, MI	43.94501	-86.27869	Yes
194	NWIS	Water	USGS	04142000	RIFLE RIVER NEAR STERLING, MI	44.07252	-84.01999	Yes
205	NWIS	Water	USGS	04159492	BLACK RIVER NEAR JEDDO, MI	43.15253	-82.62409	Yes
210	NWIS	Water	USGS	04165500	CLINTON RIVER AT MORAVIAN DRIVE AT MT. CLEMENS, MI	42.59587	-82.90881	Yes
213	NWIS	Water	USGS	04176500	RIVER RAISIN NEAR MONROE, MI	41.96060	-83.53105	Yes
220	NWIS	Water	USGS	04198000	Sandusky River near Fremont OH	41.30783	-83.15881	Yes
221	NWIS	Water	USGS	04199000	Huron River at Milan OH	41.30089	-82.60823	Yes
222	NWIS	Water	USGS	04200500	Black River at Elyria OH	41.38032	-82.10459	Yes
226	NWIS	Water	USGS	04059500	FORD RIVER NEAR HYDE, MI	45.75497	-87.20208	Yes
232	NWIS	Water	USGS	04085427	MANITOWOC RIVER AT MANITOWOC, WI	44.10722	-87.71536	Yes
244	NWIS	Water	USGS	04045500	TAHQUAMENON RIVER NEAR PARADISE, MI	46.57501	-85.26955	Yes
252	NWIS	Water	USGS	04174500	HURON RIVER AT ANN ARBOR, MI	42.28698	-83.73383	Yes
258	NWIS	Water	USGS	04193500	Maumee River at Waterville OH	41.50005	-83.71271	Yes
262	NWIS	Water	USGS	04208000	Cuyahoga River at Independence OH	41.39533	-81.62985	Yes
264	NWIS	Water	USGS	04212100	Grand River near Painesville OH	41.71893	-81.22788	Yes
270	NWIS	Water	USGS	04067500	MENOMINEE RIVER NEAR MC ALLISTER, WI	45.32581	-87.66345	Yes
273	NWIS	Water	USGS	04199500	Vermilion River near Vermilion OH	41.38199	-82.31683	Yes
274	NWIS	Water	USGS	04201500	Rocky River near Berea OH	41.40671	-81.88708	Yes
275	NWIS	Water	USGS	04213500	CATTARAUGUS CREEK AT GOWANDA NY	42.46395	-78.93503	Yes
289	NWIS	Water	USGS	04157000	SAGINAW RIVER AT SAGINAW, MI	43.41280	-83.96303	Yes
298	NWIS	Water	USGS	04218000	TONAWANDA CREEK AT RAPIDS NY	43.09311	-78.63614	Yes
308	NWIS	Water	USGS	04249000	OSWEGO RIVER AT LOCK 7, OSWEGO NY	43.45174	-76.50522	Yes
311	NWIS	Water	USGS	04260500	BLACK RIVER AT WATERTOWN NY	43.98562	-75.92465	Yes
315	NWIS	Water	USGS	04269000	ST. REGIS RIVER AT BRASHER CENTER NY	44.86366	-74.77880	Yes
322	NWIS	Water	USGS	04263000	OSWEGATCHIE RIVER NEAR HEUVELTON NY	44.59951	-75.37883	Yes
329	NWIS	Water	USGS	04040000	ONTONAGON RIVER NEAR ROCKLAND, MI	46.72077	-89.20709	Yes
347	NWIS	Water	USGS	04071765	OCONTO RIVER NEAR OCONTO, WI	44.86055	-87.98399	Yes
364	NWIS	Water	USGS	040851385	FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI	44.52860	-88.01010	Yes
380	NWIS	Water	USGS	04092750	INDIANA HARBOR CANAL AT EAST CHICAGO, IN	41.64920	-87.46865	Yes
383	NWIS	Water	USGS	04095090	BURNS DITCH AT PORTAGE, IN	41.62226	-87.17587	Yes
394	NWIS	Water	USGS	04121970	MUSKEGON RIVER NEAR CROTON, MI	43.43475	-85.66532	Yes
397	NWIS	Water	USGS	04137500	AU SABLE RIVER NEAR AU SABLE, MI	44.43640	-83.43386	Yes
421	NWIS	Water	USGS	04231600	GENESEE RIVER AT FORD STREET BRIDGE, ROCHESTER NY	43.14172	-77.61631	Yes
445	NWIS	Water	USGS	04195820	Portage River near Elmore OH	41.49116	-83.22465	Yes
459	NWIS	Water	USGS	04265432	GRASS RIVER AT CHASE MILLS NY	44.84667	-75.07806	Yes

APPENDIX B
REMOTE SENSING PLATFORMS AND RESOURCES

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Table B 1: Satellite Inventory 2010-2011

Satellite System	Country	Launch Date	Sensor	Bands/ Center Frequency	Spatial Resolution	Swath Width	Revisit Time	Polarisation	Geophysical Quantities Observed	Pros	Cons	Cost	Availability
Terra (EOS AM-1)	USA/ Japan	1999 to present	ASTER	VNIR	15 m	60 km	16 Days		SST, CHL, DOC, SM, Turbidity, TSS, HABs, Ice Cover	Good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	USGS Earth Explorer, LPDAAC, GloVIS
				SWIR	30 m								
				TIR	90 m								
			MISR	VNIR	250 - 275 m	360 km	2 - 9 Days						
			MODIS	VNIR, NIR, TIR	250 m, 500 m, 1000 m	2330 km	2 Days						LPDAAC, MichganView.org, OceanColor.gsfc.nasa.gov, LPDAAC, MRTweb
Aqua (EOS PM-1)		2002 to present											
OrbView-2	USA	1997 to 2005	SeaWiFS	VNIR	1000 - 4500 m	1500-2800 km	Daily		Surface temperature, chl, doc, sm, turbidity, TSS, HABs, ice cover	Similar product to MODIS and when combined get coverage from 1997 to present; good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	OceanColor.gsfc.nasa.gov
OrbView-3	USA	2003 to present		Panchrom.	1 m	8 km	3 Days				No longer collecting imagery		GeoEye.com
				VNIR	4 m								
ENVISAT-1	EU	2002	MERIS	VNIR (390 - 1040 nm)	260 x 300 m, 1040 x 1200 m	1150 km	35 Days		SST, CHL, DOC, SM, Turbidity, TSS, HABs, Ice Cover	Good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	OceanColor.gsfc.nasa.gov, http://envisat.esa.int/instruments/meris/
			ASAR	C-Band	~30 m	5 - 100 km	35 Days	VV, HH, VV/HH, HV/HH, VH/VV					http://earth.esa.int/ dataproducts/
			AASTR	VNIR, SWIR, TIR	1000 m	500 km	35 Days		SST, wetland mapping, ice cover, surface winds, waves, oil spills	Resolution of < 0.5 K	Data availability requires ESA PI status		http://earth.esa.int/ dataproducts/
NOAA Polar Orbiting Platforms (POES) (numerous satellites)	USA	1978 (4 channel)	AVHRR			3000 km	0.5 Days		SST, cloud mapping, land-water boundaries, snow and ice detection	Long time history; good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds		USGS Earth Explorer
		1981 (5 channel)											
		1998 (6 channel)	AVHRR	VNIR, NIR, TIR	1090 m								
		2009 (most recent launch)	AVHRR										
Landsat-1/2/3/4/5/7	USA	1984 (L5)	ETM+	VNIR	15 - 30 m	185 km	16 Days		Turbidity, water depth, HABs, chl, doc, sm, bottom type and shoreline mapping	Long time history; fine resolution	Cloud dependent; revisit time every 16 days	None	USGS Earth Explorer, USGS GloVIS
		1999 (L7)											

Table B 1: Satellite Inventory 2010-2011 - Continued

Satellite System	Country	Launch Date	Sensor	Bands/ Center Frequency	Spatial Resolution	Swath Width	Revisit Time	Polarisation	Geophysical Quantities Observed	Pros	Cons	Cost	Availability
Coriolis	USA	2003 to present	WindSat experimental passive microwave radiometer	6.8, 10.7, 18.7, 23.8, 37.0 GHz	8 - 60 km	350 - 1000 km	3	V, H ±45, L, R (10.7, 18.7, and 37 GHz); V, H (all others)	Wind direction, surface temperature, soil moisture, rain rate, ice and snow characteristics, water vapor	Fully polarimetric; all weather synoptic; sensor will operate on NPOESS	Experimental satellite not operational	Free for approved research	(JPL PO DAAC) http://podaac.jpl.nasa.gov/ windsat/calval/data
QuikSCAT	USA	1999	SeaWinds scatterometer	13.4 GHz	12.5 - 25 km	1800 km	1		Wind-speed measurements of 3 m/s to 20 m/s with 2 m/s accuracy; direction with 20 degrees accuracy; wind vector resolution of 25 km; ice cover	Daily synoptic maps; historical data back to 1999	Real-time scanning equipment failed in 2009; relatively coarse resolution	None	historical data from STAR, Center for Satellite Application and Research
ADEOS II	Japan/ USA	2002 (operational April 2003)	SeaWinds scatterometer	13.4 GHz		1800 km	1		Wind-speed measurements of 3 m/s to 20 m/s with 2 m/s accuracy; direction with 20 degrees accuracy; Wind vector resolution of 50 km	Daily synoptic maps; historical data back to 1999	Satellite mission ended in 2003 with solar panel failure; relatively coarse resolution	None; Must register	National Snow and Ice Data Center (NSIDC) website
Defense Meteorol. Satellite Program (DMSP) Block 5D	USA	1976 - 2009	SSMI/S	19 - 183 GHz	13 - 73 km	1700 km	0.5 Days (?)	V, H	Temperature, ice cover and extent, wind speed and direction	Long time history, all weather	Coarse resolution		
Commercial Satellite Systems	USA	2001	QuickBird	VNIR	0.6 - 2.4 m	16.5 km	1 - 4 Days		Water depth, HABs, bottom features and shoreline mapping	Fine spatial resolution, revisit interval; optimize collection geometry for water penetration	Expensive; same issues as other optical sensors (i.e. cloud dependent)	\$25/km² tasking; \$13/km² archive	Digitalglobe.com; Minimum task size: 78 or 92 km²
		2007 to present	WorldView 1 & 2	VNIR	0.5 m	17.6 - 22 km	2 - 5 Days					\$38/km² tasking	Digitalglobe.com; Minimum task size: 100 km²; Minimum archive order: 25 km²
		1999 to present	Ikonos	VNIR	1 - 4 m	11 km	3 - 5 Days					\$20/km² tasking; \$13/km² archive	Geoeye.com; Minimum task size: 100 km²
		2002 to present	SPOT 5	VNIR, SWIR	2.5 - 10 m	60 km	1 - 4 Days		Vegetation, atmosphere, water optical properties	Two panchromatic bands combined for higher resolution; bands for atmospheric correction and water optical properties	Expensive; slightly lower resolution	Based on Order	SIRIUS (http://www.spotimage.fr)
		2012	SPOT 6, 7	VNIR, SWIR	1.5 - 8 m	60 km							
Radarsat-1	Canada	1995-2008	SAR	C-Band	8 - 100 m	45 - 500 km	4 Days	HH	Wetland mapping, ice cover, surface winds, waves, oil spills	All-weather day/night operation; high resolution	Images are not free	\$3,600 - \$8,400 per scene	http://gs.mdacorporation .com/

Table B 1: Satellite Inventory 2010-2011 - Continued

Satellite System	Country	Launch Date	Sensor	Bands/ Center Frequency	Spatial Resolution	Swath Width	Revisit Time	Polarisation	Geophysical Quantities Observed	Pros	Cons	Cost	Availability
Radarsat-2		2007 to present			3 - 100 m	10 - 500 km	3 Days	HH, HV, VV, VH					
ALOS	Japan	2006 to present	PALSAR	L-Band	7 - 100 m	40 - 350 km	46 Days	HH, HV, VV, VH	More complex wetland mapping, ice cover, surface winds, waves, oil spills	All-weather day/night operation; high resolution; fully polarimetric	Images are not free; revisit time is a function of polarization mode		Alaska Satellite Facility (ASF) DAAC
IRS-P6	EU	2004 to present	AWiFS	VNIR, SWIR	56 m	740 km	5 Days						http://earth.esa.int/ dataproducts
TerraSAR-X	EU	2007 to present	SAR	X-Band	1 - 18 m	5 - 150 km	2 - 11 Days	HH, HV, VV, VH	Wetland mapping, ice cover, surface winds, waves, oil spills	Spotlight, strip mapping, and scanning; high geometric accuracy; will be joined by TanDEM-X twin satellite for 3D imaging	Images are not free	$2000 to $7000 per scene depending on resolution, tasked vs. archival (2008 prices); scenes are 5x10 km up to 100x150 km	(Online Archive) http://terrasar-x-archive.infoterra.de/
GOES 11 and 13	USA	2000 and 2006		VNIR	5 - 20 km	Entire hemisphere	Continuous		Clouds, water vapor, precipitation	Geostationary orbit offers continuous observations	Weather-dependent		

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Table B 2: GLOS-EA Shore Based Remote Sensing Observations

Shore Based Sensor	Application/ Geophysical Quantity Measured	EM Wavelength	Observation Frequency	Spatial Resolution	Spatial Extent	Cost $K -thousands	Pros	Cons
HF RADAR Lake (SeaSonde)	• Currents (2.5 cm/s to m/s) • Waves • Wind • Ships • Ice	3-30 MHz	10-20 minutes	300 m to 12 km based on frequency	10-25 km based on wind field and frequency	350/pair	All weather, day-night, near continuous observation	Performance issues in the Great Lakes
HF RADAR River (RiverSonde)	• Currents (2.5 cm/s to 4 m/s) • Ice	420 – 450 MHz	10-20 minutes	5-15 m	10-300 m	350/pair	All weather, day-night, near continuous observation	Performance is a function of wind generated roughness
Imaging RADAR	• Waves • Ships • Ice	5-15 GHz (C, X, and Ka band)	Variable continuous to half hour sweeps	0.01-0.5 km	5-15 km	25-50 per unit	All weather, day-night, autonomous	• High data rate protect antenna • Need easy way to record and share data
Photos and Video	• Wave state • Coastal erosion	Visible (0.4-0.7 μm)	Variable	Based on optics (Submeter)	Optics determines field of view (1-10 km)	1-15	Inexpensive if web access is available	• Weather dependent • Quantifying measurement is a challenge

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Table B 3: GLOS-EA Ship Based Remote Sensing Observations

Ship Based Sensor	Application/ Geophysical Quantity Measured	EM Wavelength	Observation Frequency	Spatial Resolution	Spatial Extent	Cost $K	Pros	Cons
VHF RADAR	• Currents	30-100 MHz	Every half hour	0.5-5 km	10-20 km from ship	150	All weather, no shore range limitation	Expensive and complicated data processing
Doppler LiDAR	• Aerosols • Atmospheric boundary layer	Visible IR	Every 10 minutes	0.1-1 km	10 km into atmosphere	150	Measurements are routine	Weather dependent
Spectrometer	• chl • DOC • sm • Turbidity • TSS • Water temp.	UV, Visible IR, and thermal	Continuous	2-25 cm spot	Profiling	75	Relatively inexpensive Collect data in all transits	Only data from ship track
Side Scan Sonar	• Water depth • Water type • 3-D map	100-500 KHz	Continuous while ship is in motion	Sub-meter based on frequency and range	A few to 10 km on both sides of ship track	50	Cost effective mapping tool	Bottom type requires domain knowledge
UV and IR Sensors	• Oil Spills	0.35 μm 8-14	Continuous	1-2 m spot	Profiling	75	Rapid response to affected area	Limited range around ship

Table B 4: Airborne Platforms

Airborne System	Company / group deploying it (examples)	Sensor	Bands	Spatial Resolution (x,y)	Height (z) accuracy	Example applications	Pros	Cons	Cost	Availability
CHARTS	US Army Corps of Engineers (JALBTCX)	SHOALS-3000 LiDAR	Green (532 nm) bathymetric & red (1064 nm) terrestrial	1-m raster DEMs made public	+/- 0.20 m	Bathymetry, bottom type mapping, near shore elevation	Terrestrial & bathymetric in 1 platform	Only 1 km offshore, 0.5 km inland typical	Free once posted online	Via NOAA Digital Coast
		Itres CASI-1500	36 multispectral visible + NIR bands (typical; 288 capable; 380-1050 nm)			Land cover mapping, bottom type	Multispectral data available to public	Nearshore only; limited areas	Free through USACE	Through contacting USACE ERDC JALBTCX group
NOAA Bahymetric LiDAR	NOAA and contractors (2010: Fugro LADS)	LADS MkII	Green (532 nm)	Up to 2-m postings	IHO SP44 Order 1 (0.5 m)	Bathymetry, bottom type mapping	Used to fill in CHARTS data gaps in Great Lakes	Bathymetry focused	Free once posted online	Via NOAA Digital Coast (2011 for Great Lakes)
Hyperspectral Imager (HSI)	NASA Glenn (with GLERL)	Hyperspectral remote sensor	400-900 nm, 2 nm band width, up to 256 bands	As needed		Harmful algal bloom mapping, vegetation mapping	Multiple bands of data at high resolution	Dedicated research mission needed	Depends on research arrangements	As negotiated with NASA Glenn for research
Deadalus Airborne Mapping System	Argon ST (formely Sensytech / Daedalus)	AA3607 Multispectral Scanner	VIS/NIR 14 channels (430 nm to 1050 nm); 2 thermal (3.0 - 5.4 & 8.5 -12.5 μm)	As needed; 0.5 - 2.0 m typical		Land cover, traffic monitoring, benthic & algal mapping	Combines multispectral with thermal data	Dedicated mission needed	Depends on mission arrangements; example recent cost was $13/sq km	As contracted
Commercial aerial imagery platforms	Photogrammetry firms (Aerocon, Woolpert, Air Land Surveys, Aero-Metric, others)	3 or 4-band digital aerial camera (such as Vexcel UltraCam)	Visible (B/G/R) with option for one NIR band	As needed; 15 cm - 2 meter typical		land cover mapping, change analysis, impervious surface mapping,	High resolution, can be flown as needed	Dedicated mission needed	$85 per square mile example for 4-band 60-cm orthophotos (color-infrared); $8 to $20 per square mile for lower resolution 3-band color or panchromatic (depending on requirements)	As contracted
		LiDAR - terrestrial tography	1064 nm (typical)	As defined by client; 0.5 - 5.0 m typical	As defined by client; 0.20 to 1.0 m typical	DEM/DTM production, building footprints/heights, floodplain analysis, watershed modeling, forest volume, etc.	Highest resolution topography available; bare earth & surface data available	Dedicated mission needed	$1,000 to $2,000 per square mile (typical) ($386 - $772 / sq km) (as quoted by NOAA LiDAR review)	As contracted
Federally-sponsored aerial imagery programs	USGS, USDA NRCS/FSA/APFO	Various 3-band and 4-band digital aerial cameras; historically film-based	3-band natural color, 4th infrared band in some collects	1.0-m (typical of NAIP and USGS orthophotos)		land cover mapping, change analysis, impervious surface mapping,	Readily available to the public for free download	Flown by government schedule, not available on demand, lower resolution than typical commercial aerial imagery	Free for download from USGS, USDA, and other sites (state GIS, AmericaView programs)	Periodically per government schedules for various Federal imagery programs; for example, Michigan available for 2005 & 2009 in digital form
Airborne multispectral LiDAR	Commercial and research firms (CH2MHill, Sec-Control Group)	multi-spectral LiDAR (SIMPL, FLS-AM, LD3)	Typically 3 wavelengths between 300 nm and 550 nm; natural color systems also available	As defined by client; similar to single-band lidar (0.5 - 5.0 m typical)		Oil spill detection (down to 1 ppm claimed); 3-D scene construction with integrated imagery	Multiple LiDAR bands can yield more information than traditional LiDAR	Costs determined on a per-project basis; typically more expensive than traditional LiDAR; some systems are still research-based	Most likely greater than typical traditional LiDAR costs	As contracted

Table B 4: Airborne Platforms - Continued

Airborne System	Company / group deploying it (examples)	Sensor	Bands	Spatial Resolution (x,y)	Height (z) accuracy	Example applications	Pros	Cons	Cost	Availability
Airborne commercial SAR	Intermap	IFSAR sensor	X-band microwave 9.2-ghz	5.0-meter postings typical DEM product	0.65-cm typical RMSE	Terrain mapping, canopy surface mapping, floodplain mapping, watershed analysis, aviation	Widespread availability, less expensive than LiDAR, sensor can collect daytime/nighttime, clouds not a problemthan LiDAR	New data collections require mission negotiated with InterMap	Already collected data: $30/sq km for DTM; $25/sq km for DSM (typical costs)	Available for Lower 48 U.S. States + Hawaii through Intermap website
NASA hyperspectral platform	NASA Jet Propulsion Lab (JPL)	AVIRIS	224 bands (hyperspectral) - 380 nm to 2500 nm, visible to near-infrared	5-m or 20-m typical, depending on altitude flown		Land cover mapping, subsurface bottom type lake mapping	Hyperspectral data available from a well-documented program	Only available in limited areas; new collects must be typically be arranged with NASA with funded program	About $10 per sq km, but flight costs must be funded ($64k per flight + $6k per flight hour)	Some Great Lakes AVIRIS imagery already available (ex: western Michigan coast, Harsens Island)
NASA Gulfstream III (platform)	NASA Jet Propulsion Lab (JPL)	UAVSAR	L-band frequency	Approx. 6m		Monitoring surface chanage (subsidence), surface roughness, ice & land cover, infrastructure, vegetation thickness	Enables all-weather surface mapping with SAR techniques	Repeat-pass onl for intererometry; dedicated mission needed requested through NASA	Depends on mission arrangements with NASA	If NASA request is approved through application process

Table B 5: Remote Sensing Resources

Remote Sensing Data Distribution Web Sites	url	Contact Person	Contact Email	Example Remote Sensing Products
AmericaView programs operating in the Great Lakes				
MichiganView	http://wiki.americaview.org/display/miview/Home	Tyler Erickson	tyler.erickson@mtu.edu	Landsat, MODIS, NAIP
WisconsinView	http://wisconsinview.org/	Sam Batzli	sabatzli@wisc.edu	Landsat, MODIS, NAIP, Orthophotography
OhioView	http://www.ohioview.org/	Kevin Czajkowski	kczajko@utnet.utoledo.edu	Landsat, DOQQ, DRG
IndianaView	http://www.indianaview.org/	Gilber Rochon	rochon@purdue.edu	
PennsylvaniaView	http://www.paview.psu.edu/	Thomas Mueller	mueller@calu.edu	
NOAA				
NOAA GLERL Coastwatch	http://coastwatch.glerl.noaa.gov/index.html	George Leshkevich	george.leshkevich@noaa.gov	AVHRR, MODIS, GOES, Contour Map
NOAA NESDIS	www.osdpd.noaa.gov/ml/index.html			MERIS, MODIS, SeaWiFS, MIRS, MSPPS
NASA data distribution sites				
GloVis	http://glovis.usgs.gov			Landsat, MODIS, Aerial, GLS
Earth Explorer	http://earthexplorer.usgs.gov			Landsat, AVHRR, ASTER (selective), Degital Elevation
LP DAAC	http://lpdaac.usgs.gov			Access to glovis, MRTweb, ASTER tasking, Data pools
Oceancolor	http://oceancolor.gsfc.nasa.gov			MODIS, MERIS, SeaWiFS, ADEOS, Nimbus-7
Glenn Research Center	http://www.nasa.gov/topics/earth/index.html			Soon to generate remote sensing data for Great Lakes
Alaska Satellite Facility Distribute Active Archive Center				
USER remote sensing access (URSA)	https://ursa.asfdaac.alaska.edu/cgi			AIRSAR, UAVSAR, PALSAR (good source for Great Lakes)

APPENDIX C
WATER QUALITY STATIONS LIST

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Table C -1. Inventory of Water Quality Monitoring Stations					
Station	**Latitude**	**Longitude**	**Notes**	**Lake**	**Agency**
1	43.09000	-82.39167	Contaminants	Huron	EnvCa
1	44.71750	-80.85667	Contaminants	Huron/GeorgianBay	EnvCa
1	43.31333	-79.75167		Ontario	EnvCa
2	46.54333	-84.74833	Contaminants	Superior	EnvCa
2	43.34000	-79.66500		Ontario	EnvCa
3	43.26833	-79.62000	Contaminants	Ontario	EnvCa
3	43.25694	-82.03833		Huron	EnvCa
3	44.72500	-80.61667		Huron/GeorgianBay	EnvCa
4	44.64583	-80.16667	Contaminants	Huron/GeorgianBay	EnvCa
4	43.32500	-81.78833		Huron	EnvCa
5	43.42500	-79.65833		Ontario	EnvCa
5	43.54833	-81.74500		Huron	EnvCa
5	46.73333	-84.79333		Superior	EnvCa
5	44.79667	-80.24333		Huron/GeorgianBay	EnvCa
6	43.46667	-79.53000		Ontario	EnvCa
6	44.73667	-80.43500		Huron/GeorgianBay	EnvCa
7	43.54667	-79.48833		Ontario	EnvCa
7	43.34167	-82.50667		Huron	EnvCa
8	43.62333	-79.45333	Contaminants	Ontario	EnvCa
8	43.56667	-82.48500		Huron	EnvCa
8	44.95278	-80.14889		Huron/GeorgianBay	EnvCa
9	43.63333	-82.21667	Contaminants	Huron	EnvCa
9	44.87167	-79.96806	Contaminants	Huron/GeorgianBay	EnvCa
9	43.58667	-79.39500		Ontario	EnvCa
10	43.66833	-79.26667		Ontario	EnvCa
10	43.75333	-81.78167		Huron	EnvCa
11	43.58500	-79.31167		Ontario	EnvCa
11	43.95667	-81.78667		Huron	EnvCa
11	44.92083	-80.60583		Huron/GeorgianBay	EnvCa
12	43.50333	-79.35333		Ontario	EnvCa
12	43.89000	-82.05667		Huron	EnvCa
12	47.03667	-85.10333		Superior	EnvCa
12	44.92000	-80.87500		Huron/GeorgianBay	EnvCa
13	43.41667	-79.40000	Contaminants	Ontario	EnvCa
13	43.75333	-82.56833		Huron	EnvCa
14	43.39333	-79.48667		Ontario	EnvCa
14	43.94167	-82.66667		Huron	EnvCa
15	43.31667	-79.44333		Ontario	EnvCa
15	45.16667	-80.29667		Huron/GeorgianBay	EnvCa
16	43.27167	-79.36000		Ontario	EnvCa
16	45.35361	-80.48667		Huron/GeorgianBay	EnvCa
17	43.22500	-79.27167	Contaminants	Ontario	EnvCa
17	44.10000	-82.86667	Contaminants	Huron	EnvCa
17	45.24500	-80.87500	Contaminants	Huron/GeorgianBay	EnvCa
17	46.71333	-85.81833		Superior	EnvCa

18	43.30333	-79.27833		Ontario	EnvCa
19	43.38333	-79.28500		Ontario	EnvCa
19	45.06667	-81.25389		Huron/GeorgianBay	EnvCa
20	43.33833	-79.19667		Ontario	EnvCa
21	43.30000	-79.12000		Ontario	EnvCa
21	45.36500	-81.19000		Huron/GeorgianBay	EnvCa
22	43.29667	-79.00500	Contaminants	Ontario	EnvCa
22	46.96833	-85.72778		Superior	EnvCa
23	47.21333	-85.63333	Contaminants	Superior	EnvCa
23	43.37000	-79.06667		Ontario	EnvCa
23	44.33333	-83.30000		Huron	EnvCa
24	43.44000	-79.12833		Ontario	EnvCa
24	45.67889	-80.83889		Huron/GeorgianBay	EnvCa
25	43.51667	-79.08000		Ontario	EnvCa
25	47.45500	-85.27500		Superior	EnvCa
26	43.60833	-79.01667		Ontario	EnvCa
26	45.83333	-80.90000		Huron/GeorgianBay	EnvCa
27	45.86667	-81.00000	Contaminants	Huron/GeorgianBay	EnvCa
27	43.70333	-78.95667		Ontario	EnvCa
27	44.19833	-82.50333		Huron	EnvCa
28	43.77500	-78.85500		Ontario	EnvCa
29	44.36667	-81.83333	Contaminants	Huron	EnvCa
29	45.58333	-81.08333	Contaminants	Huron/GeorgianBay	EnvCa
29	43.83000	-78.87000		Ontario	EnvCa
30	43.83000	-78.66167		Ontario	EnvCa
30	44.46667	-81.45333		Huron	EnvCa
31	43.88667	-78.46000	Contaminants	Ontario	EnvCa
31	47.91833	-84.91278	Contaminants	Superior	EnvCa
31	45.23833	-81.44000		Huron/GeorgianBay	EnvCa
32	43.78333	-78.43833		Ontario	EnvCa
32	44.45333	-82.34167		Huron	EnvCa
33	43.59667	-78.80167	Contaminants	Ontario	EnvCa
33	45.37028	-81.58500	Contaminants	Huron/GeorgianBay	EnvCa
33	44.50000	-82.83333		Huron	EnvCa
34	43.46167	-78.76000		Ontario	EnvCa
34	44.64000	-83.23167		Huron	EnvCa
35	43.36000	-78.73000		Ontario	EnvCa
35	45.52750	-81.66944		Huron/GeorgianBay	EnvCa
36	45.04000	-83.37833	Contaminants	Huron	EnvCa
36	43.49167	-78.38667		Ontario	EnvCa
36	45.70833	-81.62000		Huron/GeorgianBay	EnvCa
37	43.39167	-78.37000		Ontario	EnvCa
38	43.38333	-77.99000	Contaminants	Ontario	EnvCa
38	44.74000	-82.05722		Huron	EnvCa
39	43.48667	-78.00000		Ontario	EnvCa
39	44.65667	-81.37833		Huron	EnvCa
39	47.69000	-85.96667		Superior	EnvCa

39	45.87333	-81.25833		Huron/GeorgianBay	EnvCa
40	43.59000	-78.01167	Contaminants	Ontario	EnvCa
40	44.89833	-81.43667		Huron	EnvCa
41	43.71667	-78.02667	Contaminants	Ontario	EnvCa
41	45.08333	-81.53667		Huron	EnvCa
42	45.91278	-81.59500	Contaminants	Huron/GeorgianBay	EnvCa
42	43.84000	-78.03833		Ontario	EnvCa
42	45.22167	-81.82000		Huron	EnvCa
42	47.32500	-86.37167		Superior	EnvCa
43	43.95000	-78.05000		Ontario	EnvCa
43	45.01333	-82.00833		Huron	EnvCa
43	47.08000	-86.47778		Superior	EnvCa
44	45.01667	-82.68500	Contaminants	Huron	EnvCa
44	43.88167	-77.90833		Ontario	EnvCa
45	43.82000	-77.78333		Ontario	EnvCa
45	46.85667	-86.56833		Superior	EnvCa
46	43.88500	-77.69000		Ontario	EnvCa
46	45.76167	-81.79472		Huron/GeorgianBay	EnvCa
47	43.95167	-77.58833		Ontario	EnvCa
47	45.25500	-83.34667		Huron	EnvCa
48	43.86167	-77.52500		Ontario	EnvCa
48	45.27833	-82.45167		Huron	EnvCa
49	43.77167	-77.43833		Ontario	EnvCa
50	45.53500	-82.04500		Huron	EnvCa
50	46.50833	-86.56833		Superior	EnvCa
51	46.51667	-87.33667	Contaminants	Superior	EnvCa
52	43.43333	-77.71167		Ontario	EnvCa
52	45.65167	-82.64833		Huron	EnvCa
53	43.35000	-77.71167		Ontario	EnvCa
54	45.51667	-83.41667	Contaminants	Huron	EnvCa
54	43.41333	-77.57500		Ontario	EnvCa
55	43.44333	-77.43833		Ontario	EnvCa
55	45.42500	-83.65167		Huron	EnvCa
56	43.36000	-77.51500		Ontario	EnvCa
56	45.51667	-84.08333		Huron	EnvCa
57	43.27500	-77.59167	Contaminants	Ontario	EnvCa
57	46.93333	-87.30500		Superior	EnvCa
58	43.32833	-77.43833		Ontario	EnvCa
58	45.86667	-83.26667		Huron	EnvCa
59	43.38167	-77.29833		Ontario	EnvCa
59	45.76667	-83.02833		Huron	EnvCa
59	47.15917	-87.28167		Superior	EnvCa
60	43.58000	-77.20000	Contaminants	Ontario	EnvCa
60	45.90167	-83.51833		Huron	EnvCa
61	43.78667	-77.15833	Contaminants	Ontario	EnvCa
61	45.75000	-83.91667		Huron	EnvCa
62	43.88000	-77.00000		Ontario	EnvCa

62	45.67500	-84.18667		Huron	EnvCa
63	43.73167	-77.01667		Ontario	EnvCa
63	45.70333	-84.51167		Huron	EnvCa
64	45.81333	-84.75500	Contaminants	Huron	EnvCa
64	43.52500	-76.92667		Ontario	EnvCa
65	43.42333	-76.88333		Ontario	EnvCa
65	45.84500	-84.56667		Huron	EnvCa
66	43.33333	-76.84000		Ontario	EnvCa
66	45.86333	-84.29500		Huron	EnvCa
67	43.40833	-76.79500		Ontario	EnvCa
67	45.93500	-83.90000		Huron	EnvCa
68	47.01667	-88.18333	Contaminants	Superior	EnvCa
68	43.53000	-76.73167		Ontario	EnvCa
68	46.04167	-83.85333		Huron	EnvCa
69	46.07833	-84.02833	Contaminants	Huron	EnvCa
69	43.60667	-76.71333		Ontario	EnvCa
70	43.54167	-76.61833		Ontario	EnvCa
70	46.13667	-83.67167		Huron	EnvCa
71	43.47667	-76.52667	Contaminants	Ontario	EnvCa
71	46.23333	-83.74667	Contaminants	Huron	EnvCa
72	43.55000	-76.52500		Ontario	EnvCa
73	43.63333	-76.28833		Ontario	EnvCa
73	46.18667	-83.35500		Huron	EnvCa
74	43.75000	-76.51833	Contaminants	Ontario	EnvCa
75	43.84333	-76.35500		Ontario	EnvCa
76	43.95000	-76.17500		Ontario	EnvCa
76	46.00000	-83.43333		Huron	EnvCa
76	47.40167	-87.41167		Superior	EnvCa
77	43.95667	-76.40833		Ontario	EnvCa
77	45.97000	-83.19833		Huron	EnvCa
78	44.08333	-76.40667		Ontario	EnvCa
79	46.12333	-82.88583	Contaminants	Huron	EnvCa
79	44.07500	-76.52167		Ontario	EnvCa
80	47.58333	-86.95167	Contaminants	Superior	EnvCa
80	44.14167	-76.61000		Ontario	EnvCa
81	44.01667	-76.67167	Contaminants	Ontario	EnvCa
82	44.06667	-76.81167		Ontario	EnvCa
82	45.93667	-82.75833		Huron	EnvCa
82	47.85833	-86.63333		Superior	EnvCa
83	44.00000	-76.84333		Ontario	EnvCa
83	46.00000	-82.55000		Huron	EnvCa
84	46.09167	-82.55667	Contaminants	Huron	EnvCa
84	43.88667	-76.73333		Ontario	EnvCa
84	48.11333	-86.30000		Superior	EnvCa
85	43.75000	-79.08333	Contaminants	Ontario	EnvCa
86	43.25500	-79.19500		Ontario	EnvCa
87	43.29833	-77.51833		Ontario	EnvCa

87	46.06111	-82.19722		Huron	EnvCa
88	43.58833	-76.41667		Ontario	EnvCa
88	46.05556	-82.00000		Huron	EnvCa
89	43.69833	-76.41667		Ontario	EnvCa
89	45.91667	-82.16111		Huron	EnvCa
90	44.13639	-76.82500	Contaminants	Ontario	EnvCa
91	43.92000	-78.30667		Ontario	EnvCa
92	48.58333	-86.56500		Superior	EnvCa
93	43.32667	-78.86833		Ontario	EnvCa
94	43.32500	-77.21667		Ontario	EnvCa
94	44.06944	-83.08056		Huron	EnvCa
95	43.31333	-77.00000	Contaminants	Ontario	EnvCa
95	44.21250	-83.37083	Contaminants	Huron	EnvCa
95	48.21833	-87.01667		Superior	EnvCa
96	43.22333	-79.44667		Ontario	EnvCa
96	44.12639	-83.17083		Huron	EnvCa
97	43.96167	-76.12167		Ontario	EnvCa
97	44.11528	-83.52917		Huron	EnvCa
97	48.43833	-87.25333		Superior	EnvCa
98	43.93500	-76.23167	Contaminants	Ontario	EnvCa
98	43.97639	-83.57556		Huron	EnvCa
99	43.90833	-83.74167		Huron	EnvCa
100	43.82500	-83.81722	Contaminants	Huron	EnvCa
100	48.75667	-86.97583	Contaminants	Superior	EnvCa
101	43.82083	-83.62500		Huron	EnvCa
106	48.57500	-88.11667		Superior	EnvCa
113	48.14500	-87.70333	Contaminants	Superior	EnvCa
115	47.84667	-87.45667		Superior	EnvCa
118	47.60667	-87.71000		Superior	EnvCa
122	45.32500	-80.11667		Huron/GeorgianBay	EnvCa
125	47.60500	-88.21667		Superior	EnvCa
127	47.84833	-88.33667		Superior	EnvCa
130	48.10833	-88.45833		Superior	EnvCa
139	48.25333	-89.18000		Superior	EnvCa
152	47.68833	-89.46667		Superior	EnvCa
155	47.80333	-89.14667		Superior	EnvCa
157	47.61333	-89.00000		Superior	EnvCa
160	47.36667	-88.81833		Superior	EnvCa
164	47.02667	-89.03833	Contaminants	Superior	EnvCa
169	47.20667	-89.66667	Contaminants	Superior	EnvCa
171	47.45000	-89.92083		Superior	EnvCa
177	47.74667	-90.23500		Superior	EnvCa
189	46.84500	-90.18889		Superior	EnvCa
196	46.74833	-90.70333	Contaminants	Superior	EnvCa
201	47.13167	-91.11167		Superior	EnvCa
208	46.93833	-91.44833		Superior	EnvCa
221	46.78167	-92.05417	Contaminants	Superior	EnvCa

3. EXISTING PROGRAMS AND DESIGNS

A number of programs within federal agencies, universities, and private industry are tackling the challenges of integrated data management and this technical memo summarizes the current status of the key relevant projects and previous designs that should be considered when building conceptual design for a Great Lakes Observing System (GLOS).

This memo summarizes the status of a number of projects:

- NOAA IOOS Data Integration Framework (DIF)—a framework to improve the management and delivery of an initial subset of ocean observations. The DIF will establish the technical infrastructure, standards, and protocols needed to improve delivery of the defined core variables.
- Ocean Observatories Initiative (OOI) — National Science Foundation's contribution to the U.S. Integrated Ocean Observing System (IOOS). This initiative looks to discoveries enabled by new technologies to construct a long-term network infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor.
- Lockheed Martin, Integrated Ocean Observing System (IOOS): Conceptual Design, 2006
- Raytheon, Integrated Ocean Observing System (IOOS): Conceptual Design, 2006
- U.S Navy Metoc Data Management
- U.S Coast Guard Environmental Data Server (EDS)
- Hydrology Community

592	45.88333	-82.15000		Huron	EnvCa
593	45.60500	-81.88833		Huron	EnvCa
725	43.63833	-79.36167		Ontario	EnvCa
726	43.63222	-79.37944		Ontario	EnvCa
879	42.50694	-79.90000	Contaminants	Erie	EnvCa
880	41.93583	-81.65389	Contaminants	Erie	EnvCa
881	41.96889	-83.20806	Contaminants	Erie	EnvCa
882	41.76583	-83.31000	Contaminants	Erie	EnvCa
885	41.51917	-82.64056	Contaminants	Erie	EnvCa
886	42.53833	-79.61722		Erie	EnvCa
887	42.64722	-79.69167	Contaminants	Erie	EnvCa
888	42.28056	-81.67056	Contaminants	Erie	EnvCa
889	42.11000	-81.57472		Erie	EnvCa
909	43.28056	-79.87278		Ontario	EnvCa
918	43.28556	-79.79389		Ontario	EnvCa
926	43.30472	-79.81500		Ontario	EnvCa
931	42.84944	-78.94139	Contaminants	Erie	EnvCa
932	42.79139	-79.20778		Erie	EnvCa
933	42.82500	-79.56667	Contaminants	Erie	EnvCa
934	42.70806	-79.50833		Erie	EnvCa
935	42.59139	-79.46611	Contaminants	Erie	EnvCa
936	42.47472	-79.40861		Erie	EnvCa
937	42.71722	-80.25000	Contaminants	Erie	EnvCa
938	42.63361	-80.05861		Erie	EnvCa
939	42.56667	-79.91667		Erie	EnvCa
940	42.44167	-79.83333		Erie	EnvCa
941	42.32500	-79.83333		Erie	EnvCa
942	42.25917	-79.83333	Contaminants	Erie	EnvCa
943	42.57500	-80.64167		Erie	EnvCa
944	42.53333	-80.64167	Contaminants	Erie	EnvCa
945	42.40000	-80.64167		Erie	EnvCa
946	42.16667	-80.64167	Contaminants	Erie	EnvCa
947	41.99167	-80.64167		Erie	EnvCa
948	41.95694	-80.64167		Erie	EnvCa
949	42.25000	-81.10833	Contaminants	Erie	EnvCa
950	42.58778	-81.44167		Erie	EnvCa
951	42.47500	-81.44167	Contaminants	Erie	EnvCa
952	42.35833	-81.44167		Erie	EnvCa
953	42.20833	-81.44167		Erie	EnvCa
954	42.02500	-81.44167		Erie	EnvCa
955	41.80000	-81.44167		Erie	EnvCa
956	41.69167	-81.44167		Erie	EnvCa
957	41.68333	-81.74167		Erie	EnvCa
958	41.52500	-81.70833	Contaminants	Erie	EnvCa
959	42.19500	-82.18333		Erie	EnvCa
960	42.10000	-82.18333	Contaminants	Erie	EnvCa
961	41.90833	-82.18333		Erie	EnvCa

962	41.71667	-82.18333		Erie	EnvCa
963	41.57500	-82.18333	Contaminants	Erie	EnvCa
964	41.48333	-82.18333		Erie	EnvCa
965	41.50000	-82.50000		Erie	EnvCa
966	41.98333	-82.62500		Erie	EnvCa
967	41.89167	-82.66667		Erie	EnvCa
968	41.74167	-82.73333		Erie	EnvCa
969	41.60833	-82.92500		Erie	EnvCa
970	41.82500	-82.97500	Contaminants	Erie	EnvCa
971	41.95000	-83.05000		Erie	EnvCa
972	41.86667	-83.20000		Erie	EnvCa
973	41.79167	-83.33333		Erie	EnvCa
974	41.72500	-83.15000		Erie	EnvCa
1001	43.28667	-79.84250		Ontario	EnvCa
33A	43.56944	-78.80750		Ontario	EnvCa
41A	43.71778	-78.02500		Ontario	EnvCa
57A	43.30556	-77.63778		Ontario	EnvCa
1	46.99331	-85.16111	Master	Superior	GLNPO
2	47.36056	-85.62056		Superior	GLNPO
3	46.89444	-85.85139		Superior	GLNPO
4	47.25917	-86.34833		Superior	GLNPO
5	46.77472	-86.55556		Superior	GLNPO
6	43.46667	-82.00000		Huron	GLNPO
6	48.55861	-86.37694		Superior	GLNPO
7	48.07417	-86.59139		Superior	GLNPO
8	47.60583	-86.81778	Master	Superior	GLNPO
9	42.53833	-79.61667		Erie	GLNPO
9	43.63333	-82.21667		Huron	GLNPO
9	48.43667	-87.08611		Superior	GLNPO
10	42.68000	-79.69167		Erie	GLNPO
10	47.51417	-87.54611		Superior	GLNPO
11	42.38078	-86.99823		Michigan	GLNPO
11	48.34361	-87.82528		Superior	GLNPO
12	43.89000	-82.05667		Huron	GLNPO
12	43.50333	-79.35333		Ontario	GLNPO
12	47.85611	-88.04194		Superior	GLNPO
13	48.22972	-88.54444		Superior	GLNPO
14	47.74083	-88.73750		Superior	GLNPO
15	42.51667	-79.89333	Master	Erie	GLNPO
15	44.00000	-82.35000	Master	Huron	GLNPO
15	48.08275	-89.25333		Superior	GLNPO
16	47.62139	-89.46306		Superior	GLNPO
17	42.73272	-87.41663		Michigan	GLNPO
17	47.16444	-89.66194		Superior	GLNPO
18	42.73333	-87.00000	Master	Michigan	GLNPO
19	42.73300	-86.58317		Michigan	GLNPO
19	47.51444	-90.15194		Superior	GLNPO

19	47.37028	-90.85389		Superior	GLNPO
23	43.13250	-86.99867		Michigan	GLNPO
25	43.51667	-79.08000		Ontario	GLNPO
27	43.60000	-86.91667	Master	Michigan	GLNPO
27	44.19833	-82.50333		Huron	GLNPO
30	42.43000	-81.20500		Erie	GLNPO
31	42.25333	-81.10667		Erie	GLNPO
32	42.08167	-81.01167		Erie	GLNPO
32	44.45333	-82.34167		Huron	GLNPO
32	44.14000	-87.23333		Michigan	GLNPO
33	43.59667	-78.80167	Master	Ontario	GLNPO
34	44.09000	-86.76667		Michigan	GLNPO
36	41.93500	-81.47833		Erie	GLNPO
37	42.11000	-81.57500		Erie	GLNPO
37	44.76167	-82.78333		Huron	GLNPO
38	42.28167	-81.67167		Erie	GLNPO
38	44.74000	-82.06000		Huron	GLNPO
40	44.75932	-86.96678		Michigan	GLNPO
41	44.73667	-86.72167	Master	Michigan	GLNPO
41	43.71667	-78.02667		Ontario	GLNPO
42	41.96500	-82.04167		Erie	GLNPO
43	41.78833	-81.94500		Erie	GLNPO
43	41.78833	-81.94500		Erie	GLNPO
45	45.13667	-82.98333	Master	Huron	GLNPO
47	45.17733	-86.37500		Michigan	GLNPO
48	45.27833	-82.45167		Huron	GLNPO
49	43.77167	-77.43833		Ontario	GLNPO
53	45.45000	-82.91500		Huron	GLNPO
54	45.51667	-83.41667	Master	Huron	GLNPO
55	43.44333	-77.43833	Master	Ontario	GLNPO
58	41.68500	-82.93333		Erie	GLNPO
59	41.72667	-83.15000		Erie	GLNPO
60	41.89167	-83.19667		Erie	GLNPO
60	43.58000	-77.20000		Ontario	GLNPO
61	41.94667	-83.04500		Erie	GLNPO
61	45.75000	-83.91667		Huron	GLNPO
63	42.41667	-79.80000		Erie	GLNPO
63	43.73167	-77.01667		Ontario	GLNPO
73	41.97778	-81.75694		Erie	GLNPO
78	42.11667	-81.25000	Master	Erie	GLNPO
91	41.84083	-82.91667	Master	Erie	GLNPO
92	41.95000	-82.68667		Erie	GLNPO
93	44.10000	-82.11667		Huron	GLNPO
20B	46.88333	-90.28333	Benthic	Superior	GLNPO
21B	47.15833	-87.78611	Benthic	Superior	GLNPO
22B	46.80000	-91.75000	Benthic	Superior	GLNPO
23B	46.59750	-84.80694	Benthic	Superior	GLNPO

30B	43.93333	-86.56667	Benthic	Michigan	GLNPO
31B	43.91667	-87.61667	Benthic	Michigan	GLNPO
42B	44.77056	-87.21278	Benthic	Michigan	GLNPO
46B	43.10000	-86.37222	Benthic	Michigan	GLNPO
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49B	45.49361	-87.03278	Benthic	Michigan	GLNPO
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64B	43.58333	-76.33333	Benthic	Ontario	GLNPO
64B	43.58333	-76.25000	Benthic/Fish	Ontario	GLNPO
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820017	42.05417	-83.15250		Detroit	MDNRE

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APPENDIX D
REAL-TIME AND WQ STATION MAPS

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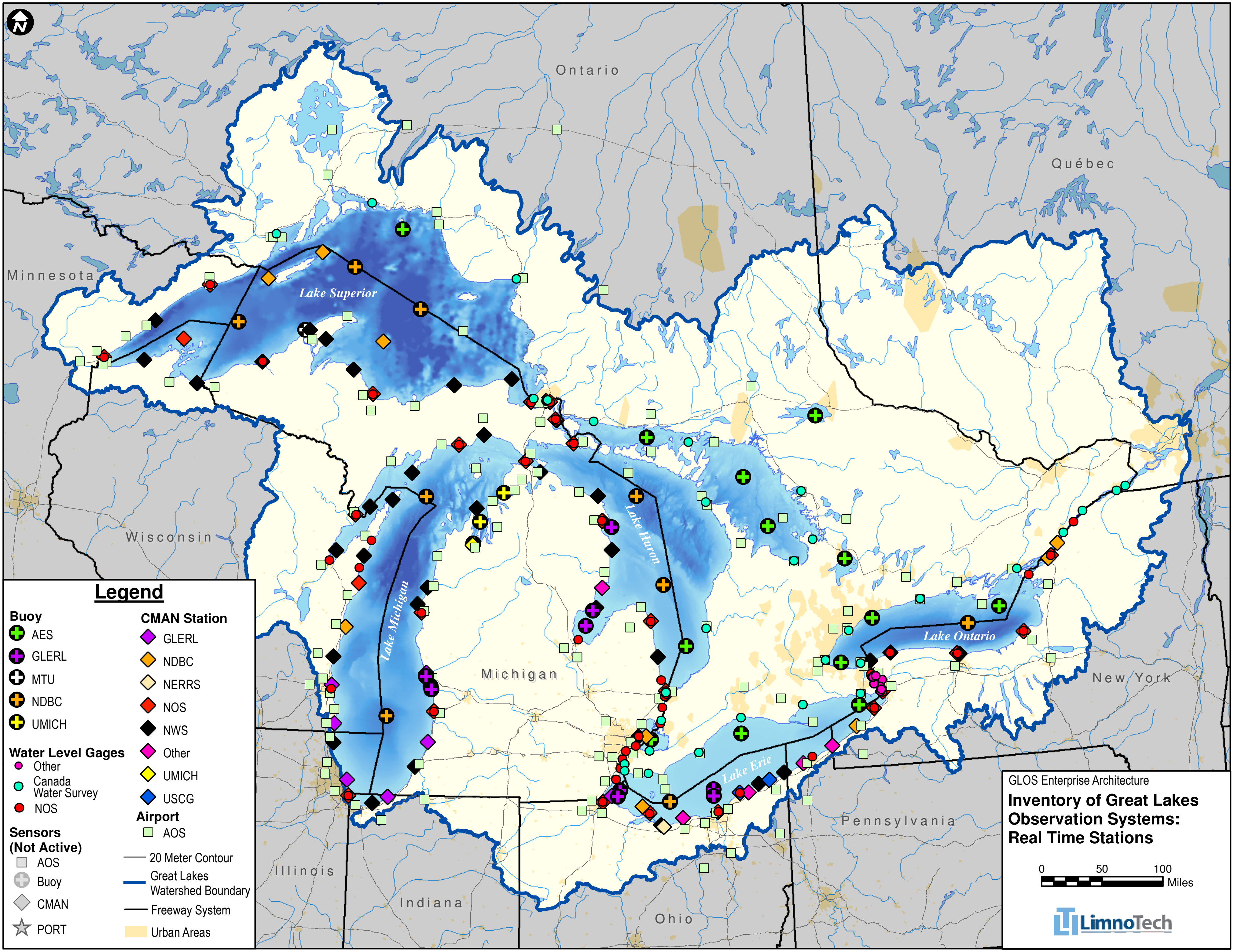

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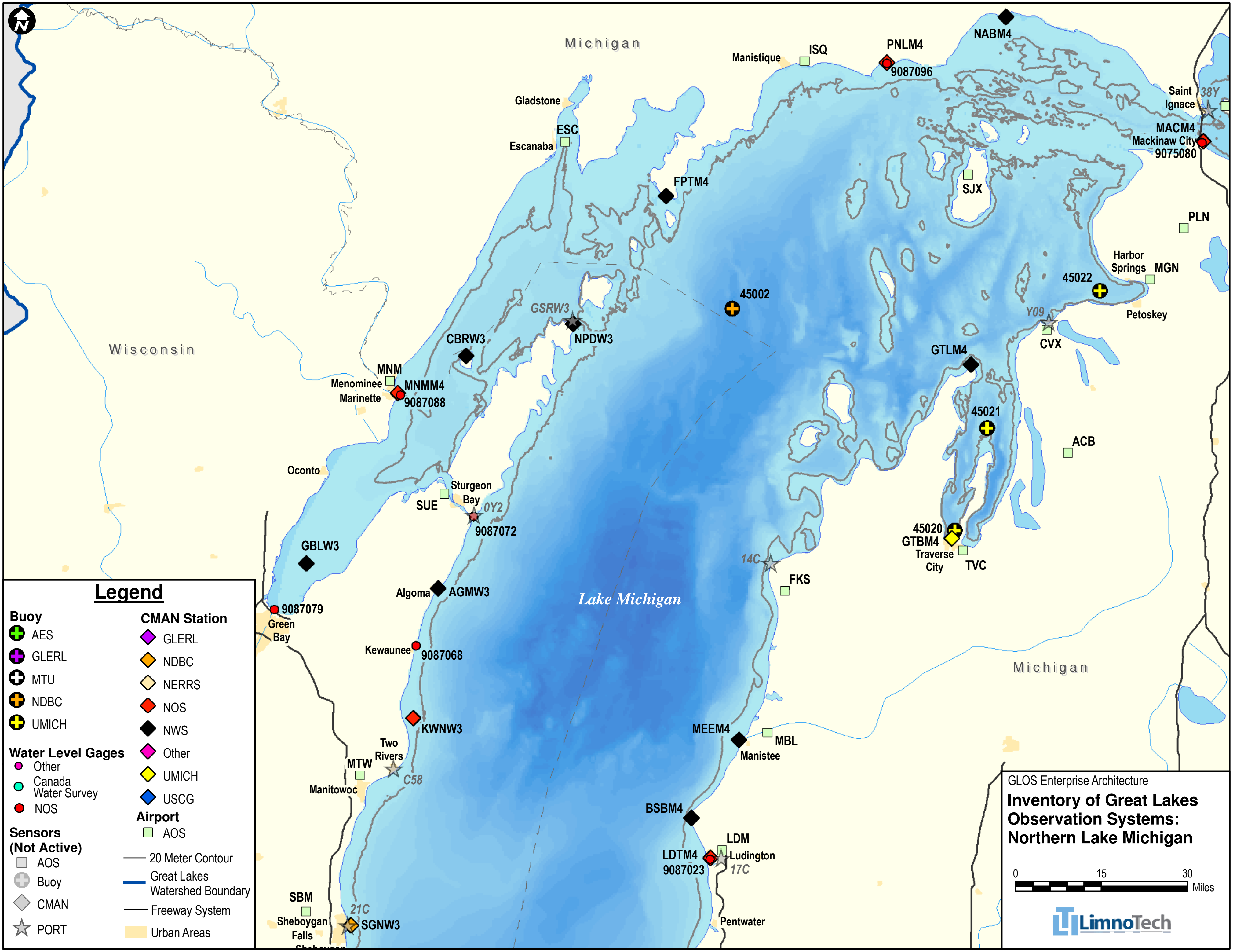
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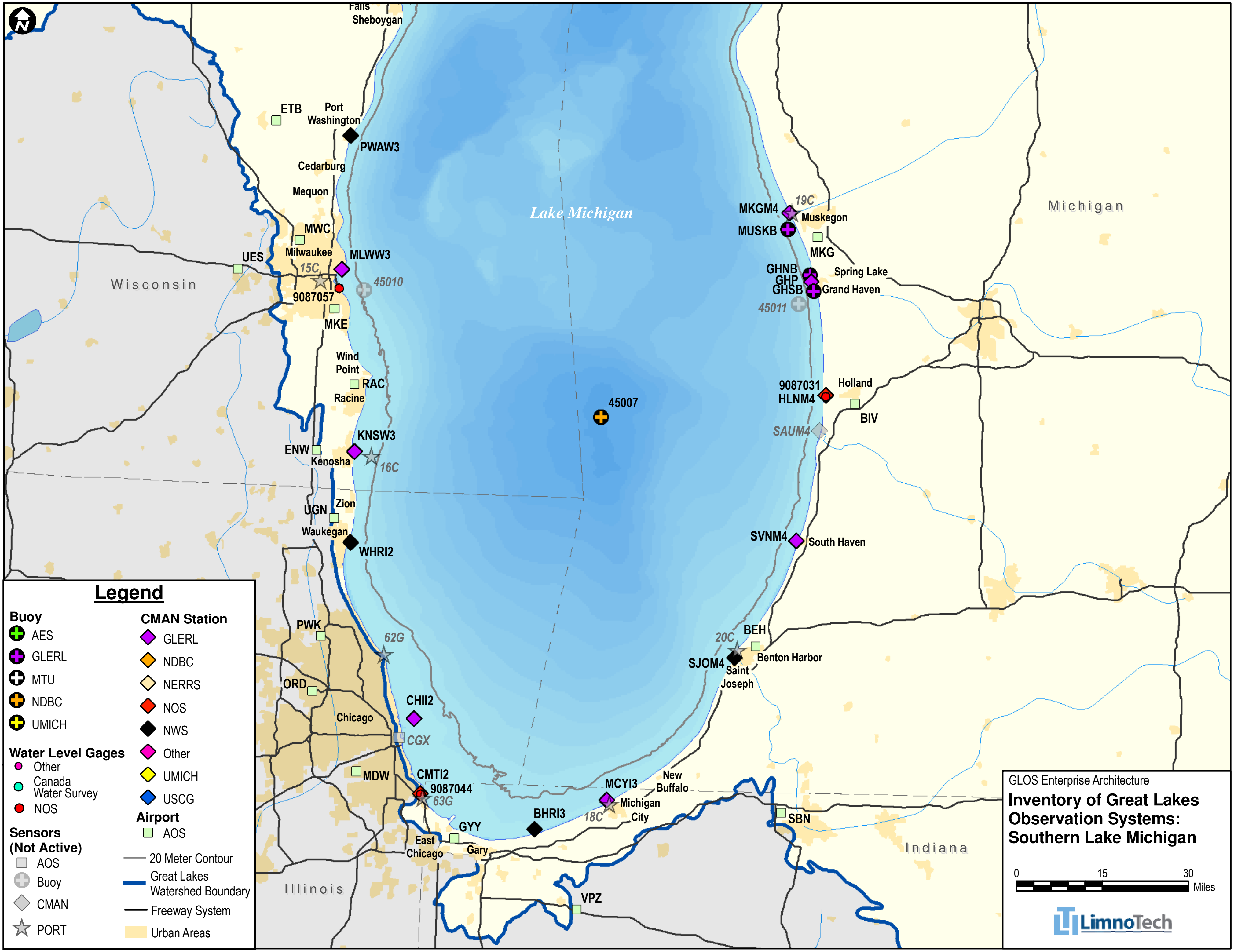
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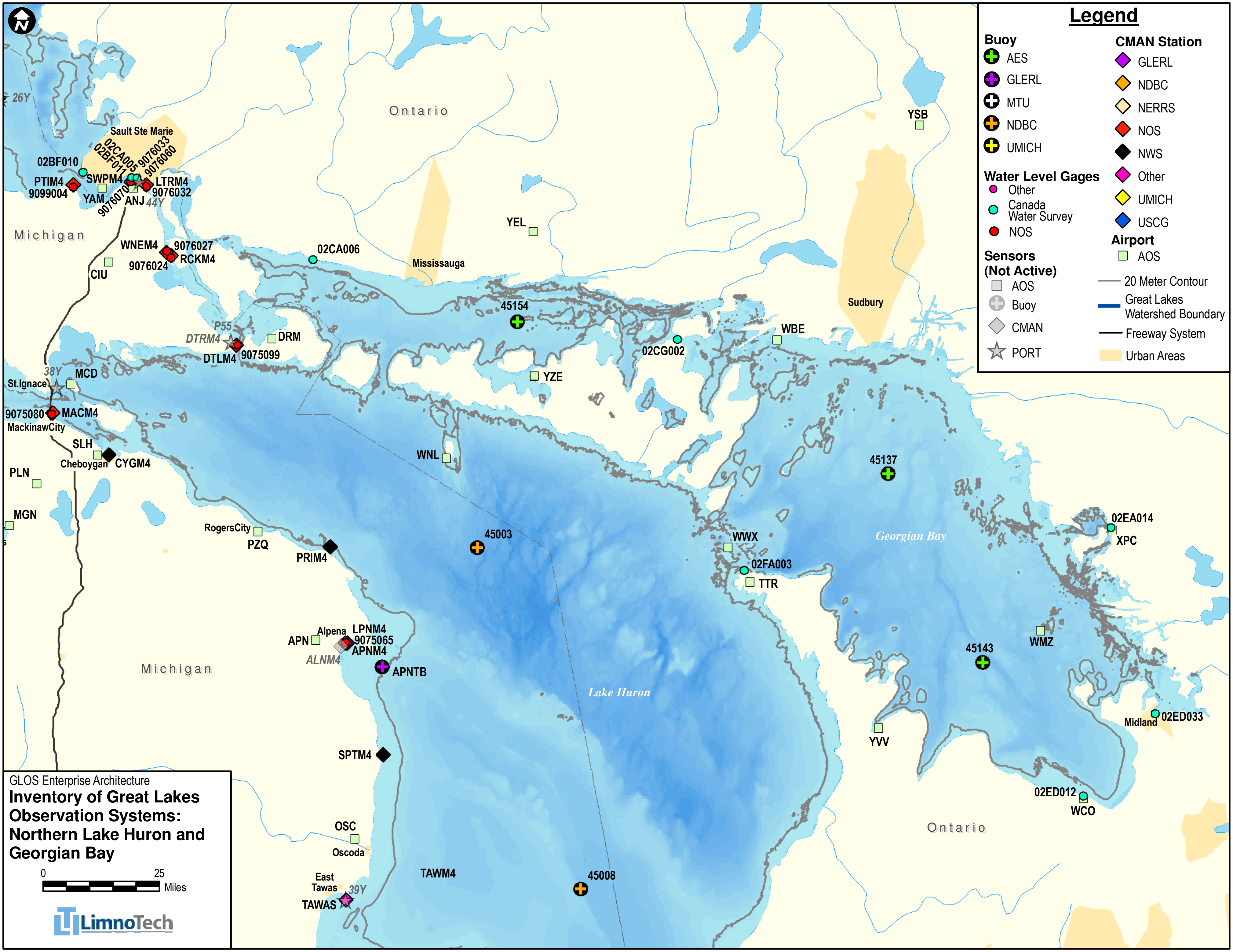

GLOS Enterprise Architecture

Inventory of Great Lakes Observation Systems: Northern Lake Huron and Georgian Bay

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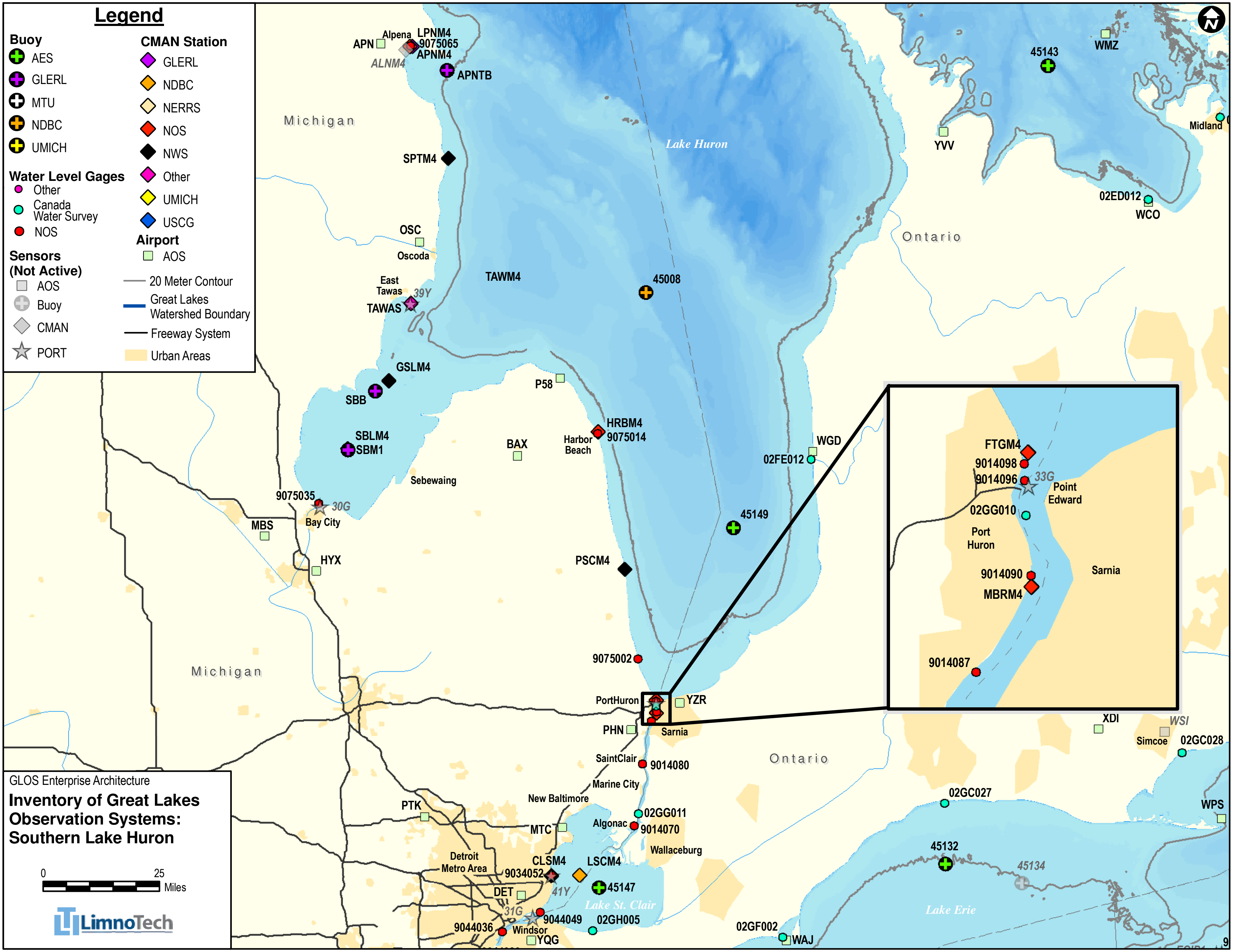

GLOS Enterprise Architecture

Inventory of Great Lakes Observation Systems: Southern Lake Huron

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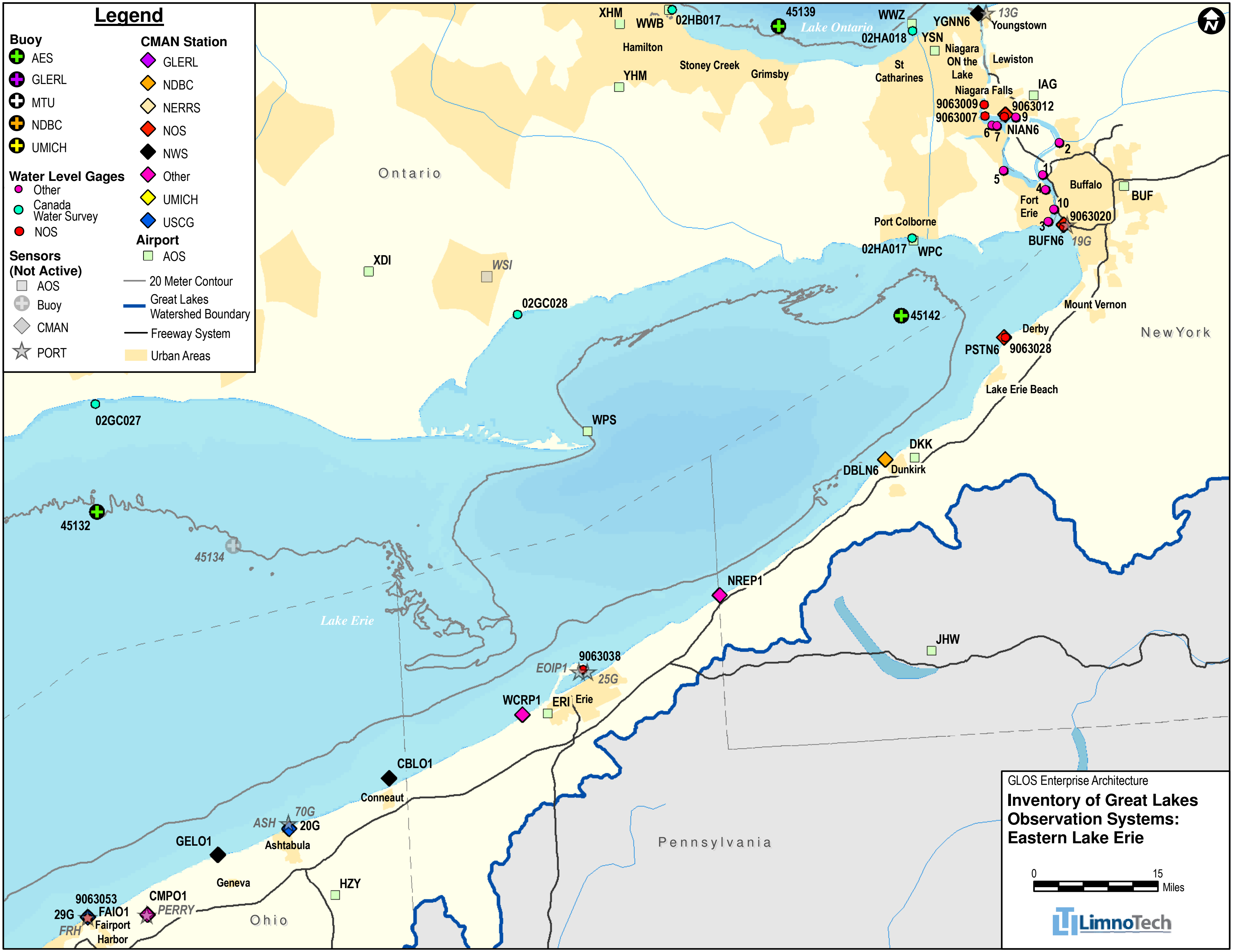

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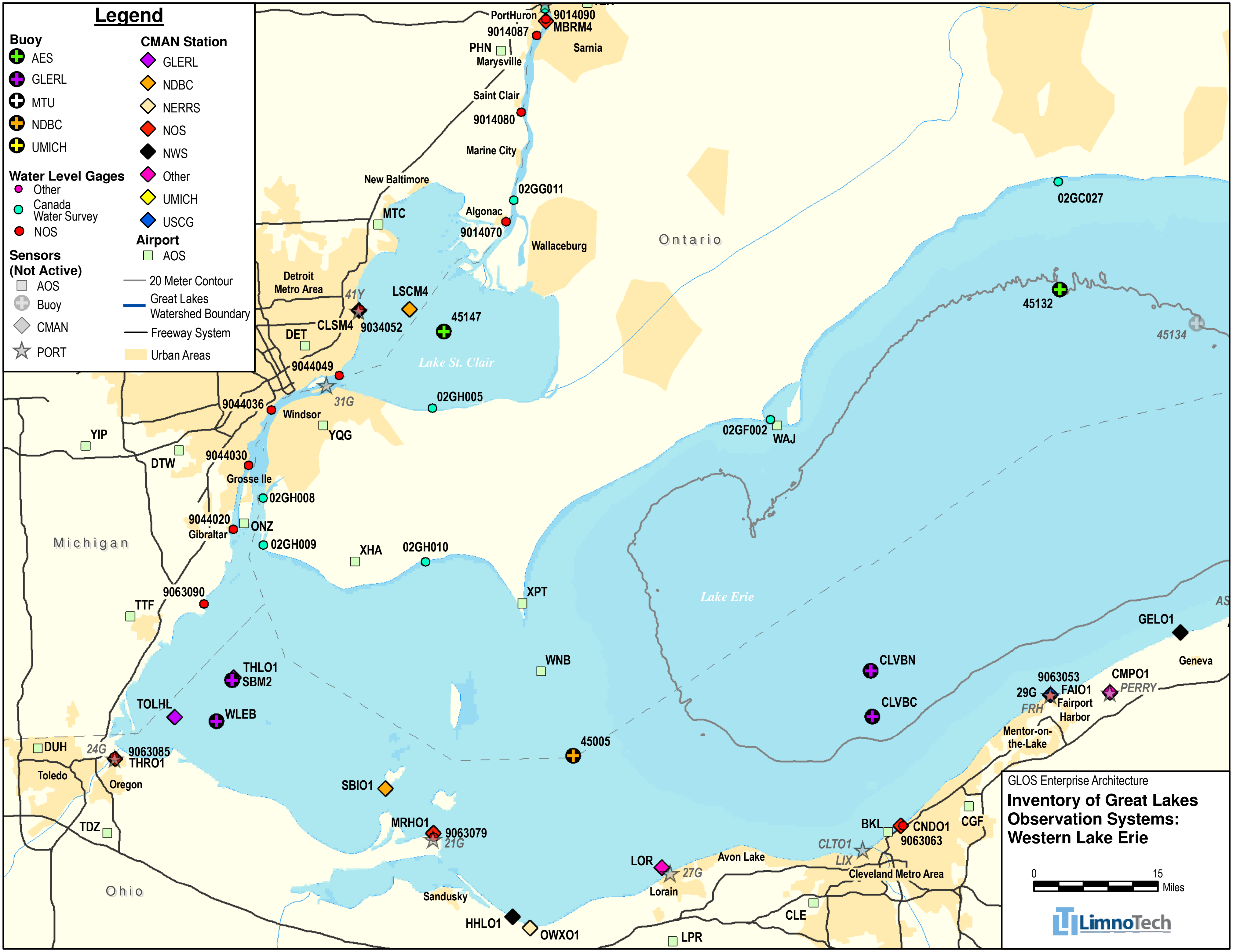

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GLOS Enterprise Architecture
Inventory of Great Lakes Observation Systems: Western Lake Erie
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4. INTEGRATED OCEAN OBSERVING SYSTEM (IOOS)

4.1 IOOS SYSTEMS

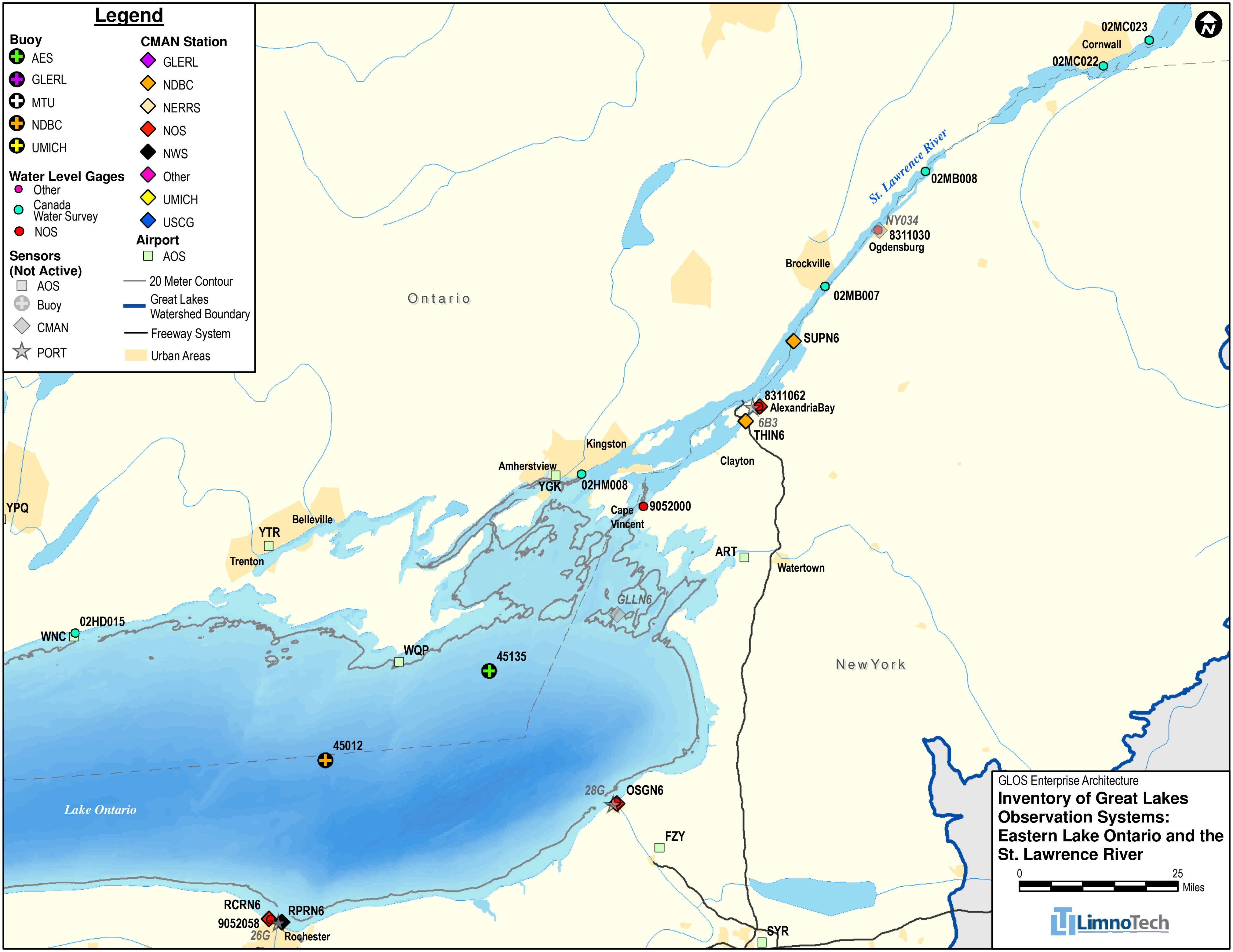
In 2004, Ocean.US in collaboration with federal agencies (NOAA, NASA, NSF, Navy, EPA, USACE, USGS, MMS, and USCG), developed the first Integrated Ocean Observing System (IOOS) plan. IOOS was described as a coordinated national and international network of observations and telemetry (O&T) elements, data management and communications (DMAC) elements, and data analyses and modeling (DAM) elements that systematically and efficiently acquire and disseminate data and information on past, present and future states of the oceans and U.S. coastal waters to the head of tide. The IOOS is the ocean and coasts component of the IEOS and the U.S. contribution to GOOS and GEOSS.

Figure 1. Relationships between the IOOS, U.S. IEOS and the international observing systems, GOOS and GEOSS.

The system was envisioned to aid in the achievement of seven societal goals:

1. Improve predictions of climate change and evaluate its impact
2. Improve the safety and efficiency of maritime operations
3. Effectively mitigate the effects of natural hazards
4. Improve national and homeland security
5. Reduce public health risks
6. More effectively protect and restore healthy coastal ecosystems
7. Enable the sustained use of ocean and coastal resources.

The new IOOS program office has re-energized the IOOS framework with a mission is to "lead the integration of ocean, coastal, and Great Lakes observing capabilities, in collaboration with Federal and non-Federal partners, to maximize access to data and generation of information



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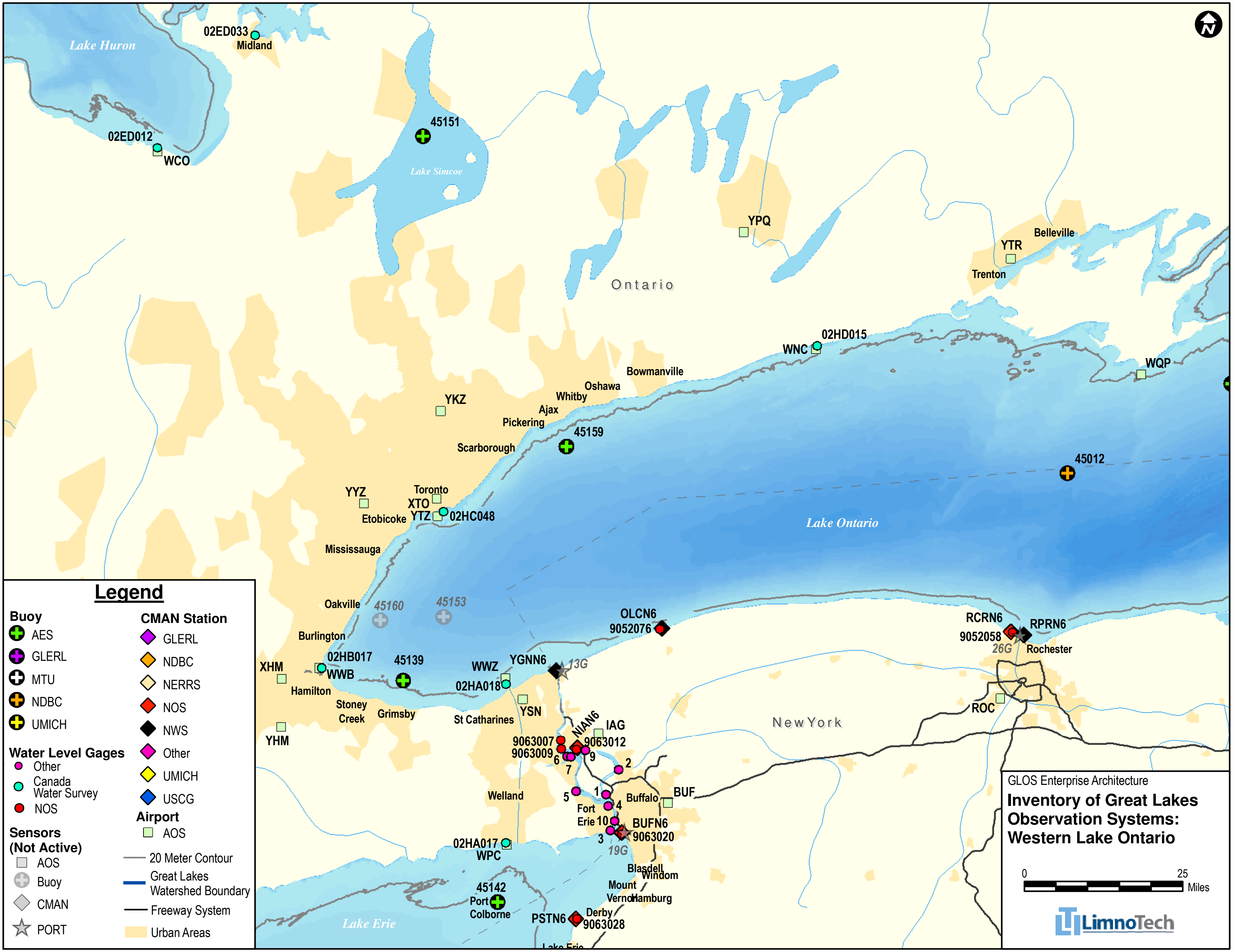
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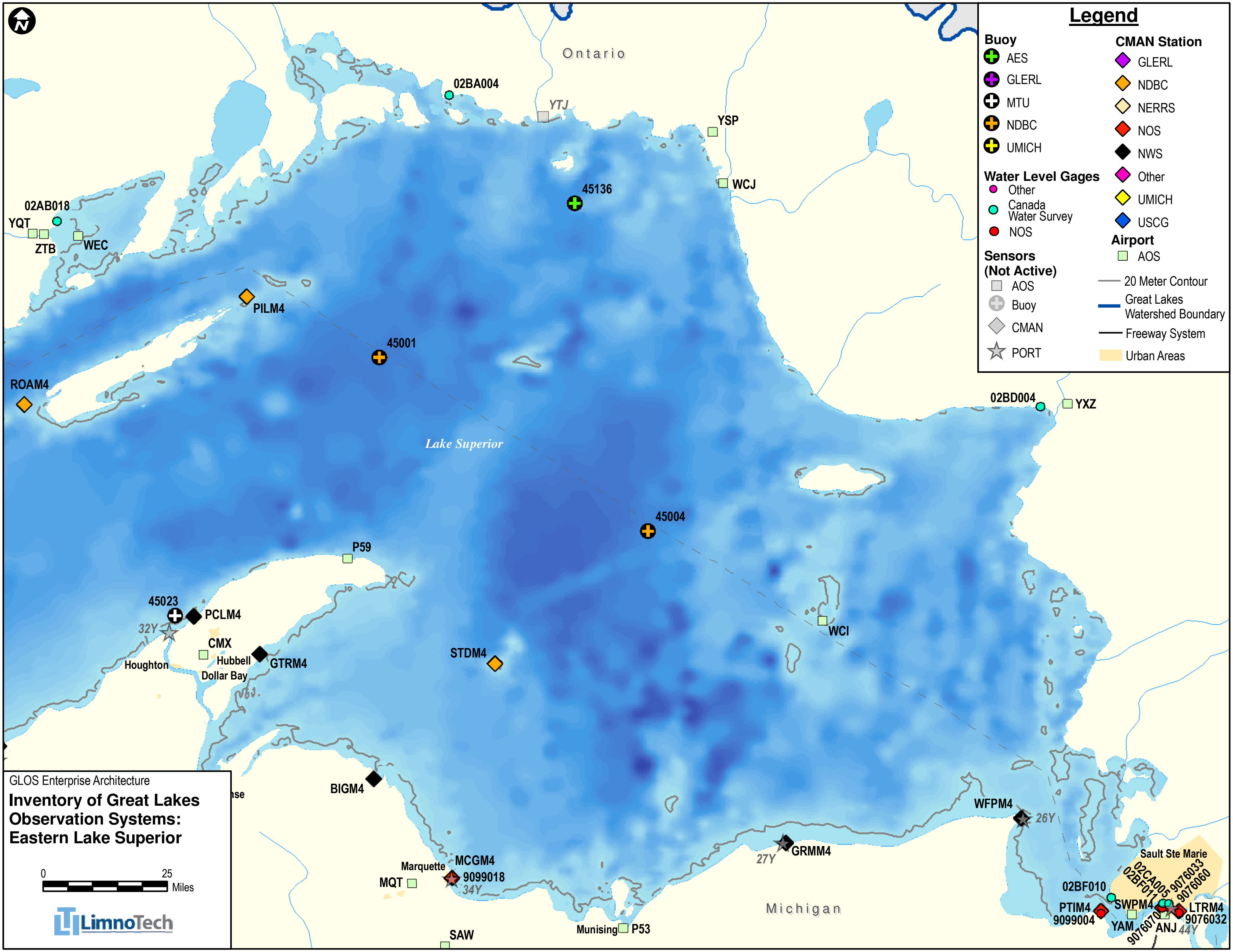
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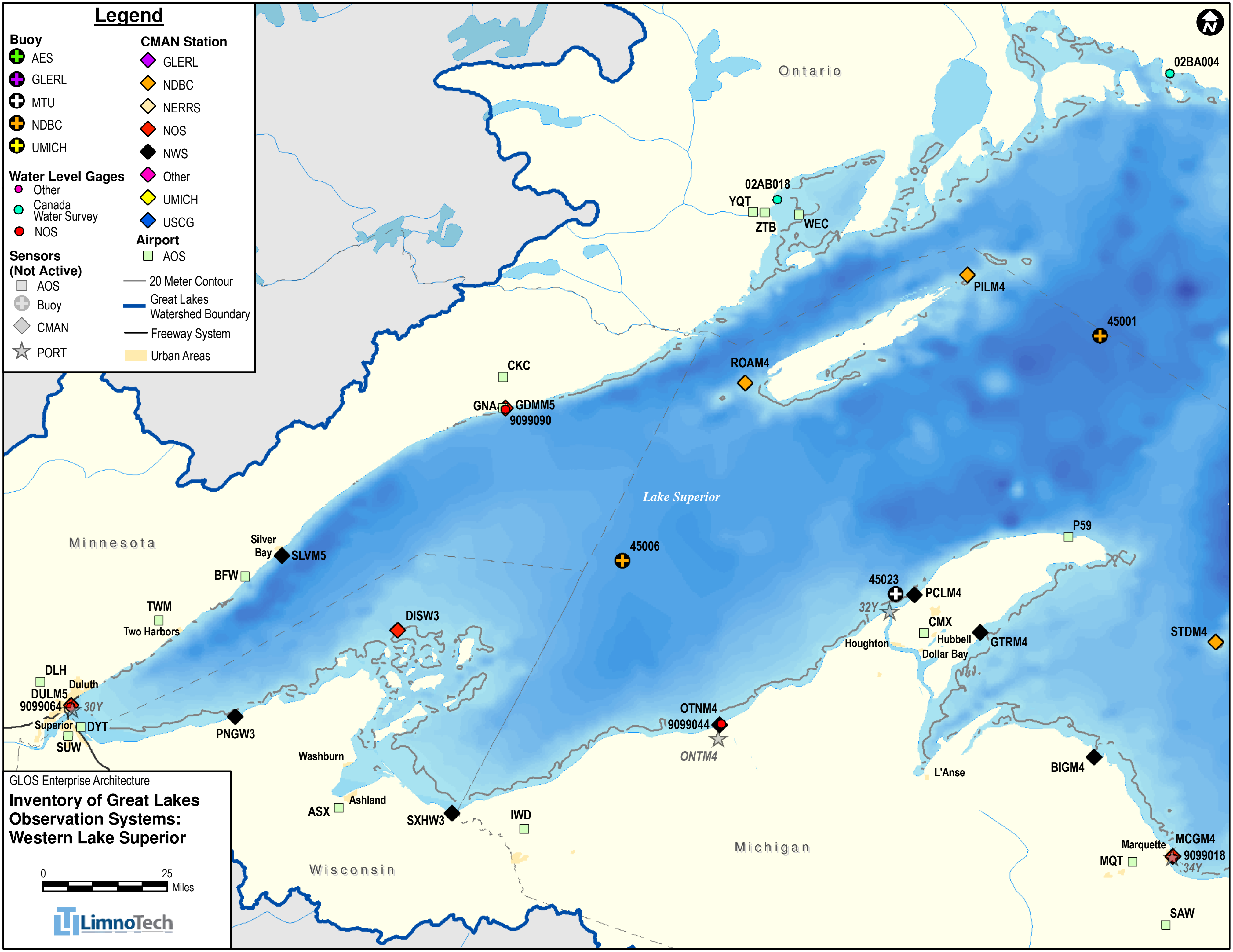
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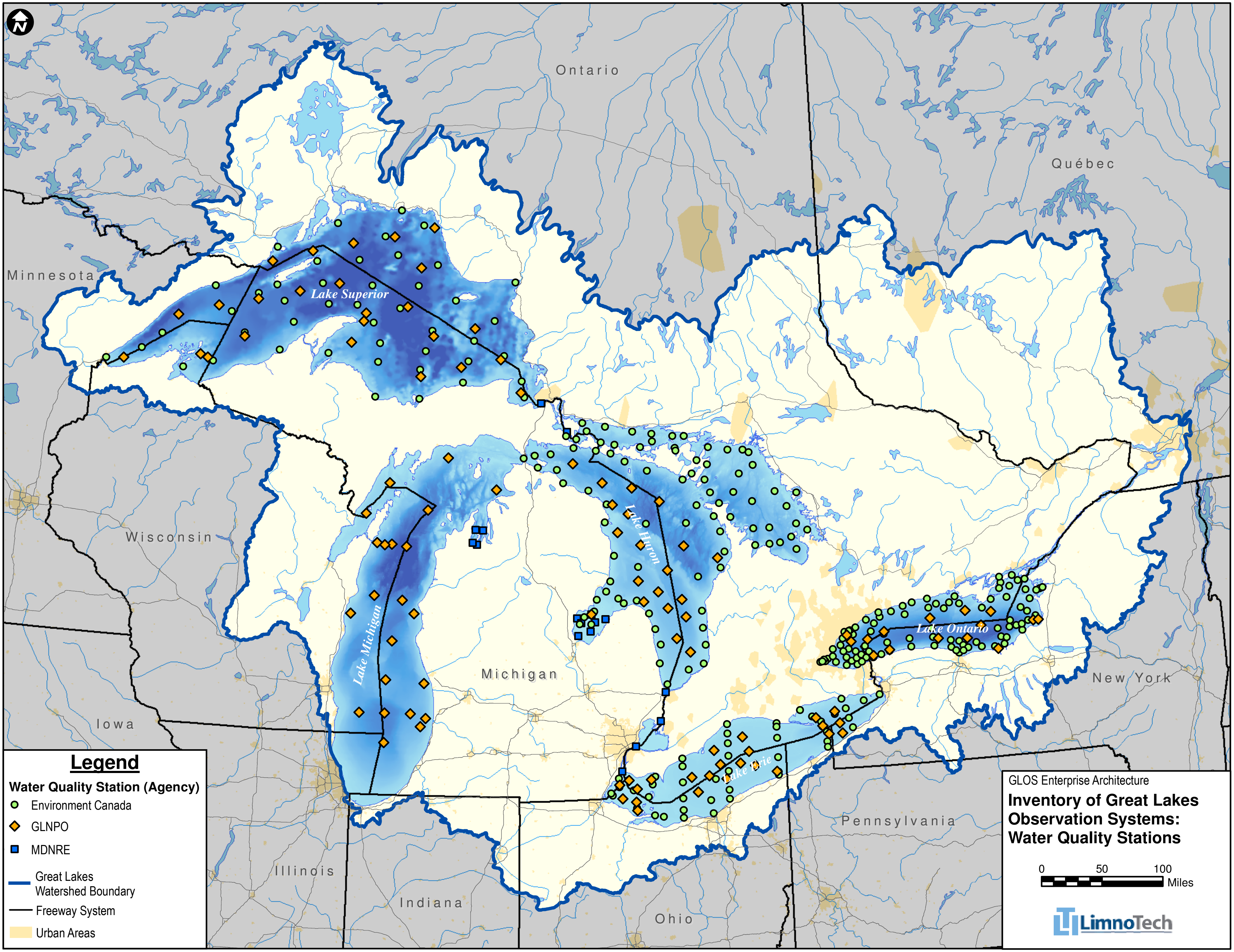

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Freeway System
Urban Areas
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Inventory of Great Lakes Observation Systems: Water Quality Stations
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products, inform decision making, and promote economic, environmental, and social benefits to our nation and the world."

Pieces of the observing infrastructure and interoperability goals have been advanced but the national funding levels are nowhere near what the design estimates suggested. In 2006, Ocean.us awarded 2 contracts, one to Raytheon and one to Lockheed Martin to provide a conceptual design for IOOS –summaries of these are provided below. Despite the shortfall of funding (Raytheon estimated that over $2B would be required for 2008 to meet the design requirements), many of the early goals such as the IOOS Program office, the regional associations and some portals have successfully been established. There is a strong focus on the development and implementation of standards to enhance interoperability and significant progress has been made to share observing and model data between the regional associations, the federal agencies, and the user community.

Figure 2. IOOS Regional Associations

IOOS is made up of 11 regional associations (RA’s) and these grass roots regional associations continue to show considerable advancement, initially through “plus up” federal funding and more recently through the IOOS Program Office that funds the 11 regional associations on the order of approximately $2M per year. The regional associations use this funding in a variety of ways including deployment of observing platforms such as in-situ buoys, high frequency radar, gliders, and numerical modeling efforts that integrate real-time data for model forecasts for the region. Each regional association also has a data management and communications (DMAC) component that focuses on integration of the data from the different researchers in the RA. Each of the RAs has very close university relationships with most of the work, including data management, being performed by university researchers.

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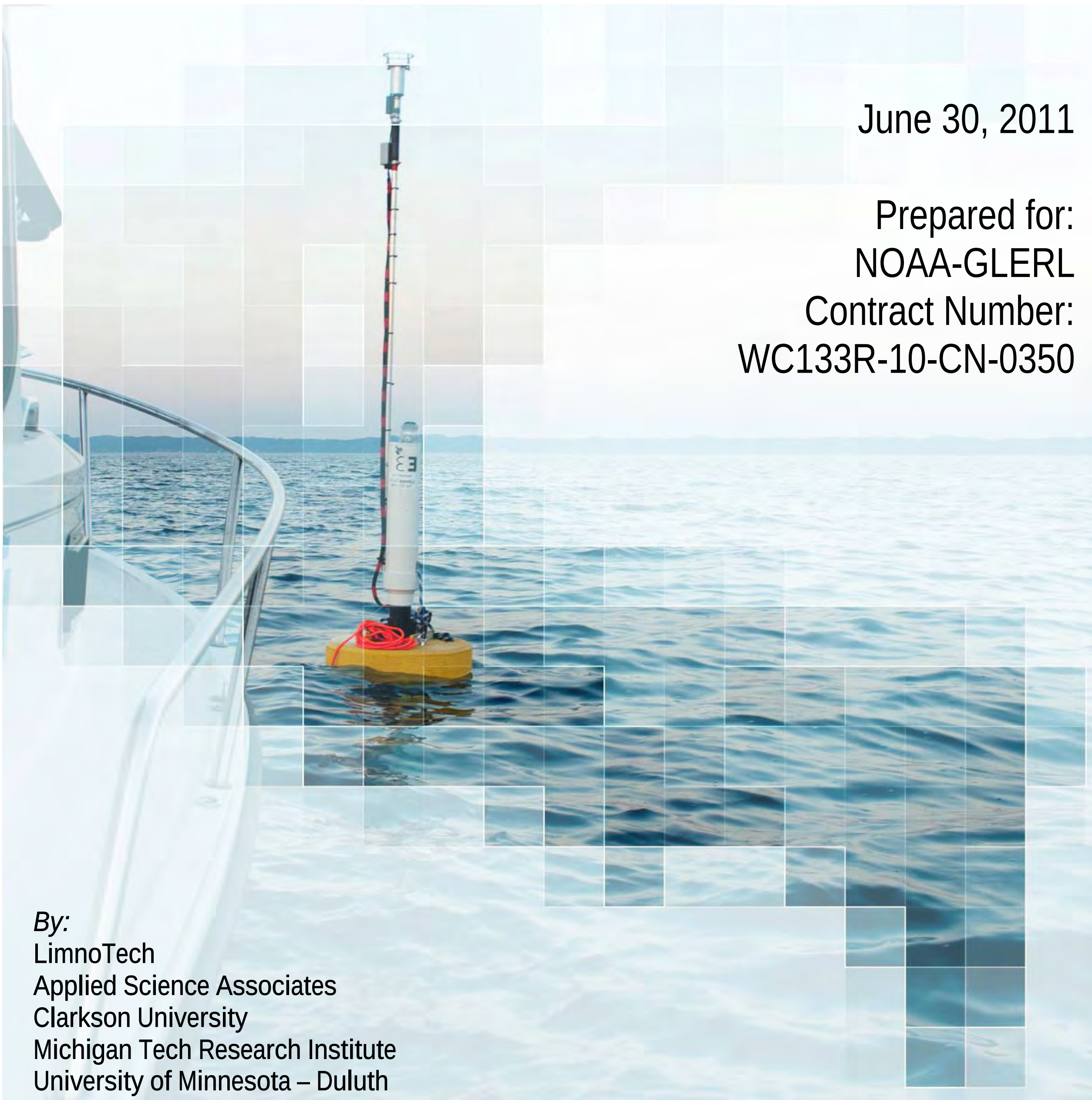
TECHNICAL MEMORANDUM 4: EXISTING DMAC INFRASTRUCTURE IN THE GREAT LAKES

Near-Term Design of the Great Lakes Observing System Enterprise Architecture



June 30, 2011

Prepared for:
NOAA-GLERL
Contract Number:
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Technical Memorandum 4: Existing DMAC Infrastructure in the Great Lakes

Near-Term Design of the Great Lakes Observing System Enterprise Architecture

June 30, 2011

Prepared for:

NOAA-GLERL
(Contract Number: WC133R-10-CN-0350)

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1. SUMMARY

This memo is the fourth technical memorandum in a series of six that summarizes the current observations systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six tech memos cover the following topics:

1. Current state of data management in support of observing systems
2. Cost associated with observing systems
3. Inventory of Great Lakes observing systems and monitoring programs
4. Summary of Great Lakes DMAC infrastructure
5. Great Lakes models, scale, and operational status
6. Catalogue of Great Lakes user needs

Each of these tech memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

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2. OVERVIEW

The goal of this memorandum is to inventory and appreciate existing data management and communications (DMAC) infrastructure - where data are stored, and what the pathways are from sensor to store and from store to consumer. This effort will help the GLOS EA Team consider how existing infrastructure can be built on, incorporated, or used as models for the completed Enterprise Architecture. Its focus is primarily on the existing GLOS node, with information also provided for other efforts in the Great Lakes region. IOOS efforts in other regions of the US are discussed in Technical Memorandum 1.

The inventory is based on a list of data owners, aggregators, and disseminators identified in internal GLOS EA team discussions, each contacted by LimnoTech to acquire summaries of existing DMAC infrastructure. The contacts broke out into the following groupings:

- GLOS. The Great Lakes Observing System (GLOS) is the Great Lakes Region node of the national Integrated Ocean Observing System (IOOS). One of eleven Regional Associations in the IOOS, the GLOS links to weather, buoy, water level and ship data throughout the Great Lakes as well as publishing a number of modeling nowcast and forecast products. These products are aggregated and disseminated in close collaboration with the Great Lakes Commission. The existing GLOS DMAC infrastructure is a logical starting point for consideration as a basis for future DMAC infrastructure.
- Federal Agencies. A number of Federal agencies, including the National Oceanic and Atmospheric Administration (NOAA), the US Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and the US Environmental Protection Agency (EPA) collect and publish Great Lakes data from sensors. DMAC-related agency activities are generally national in scope and support activities across all IOOS regions.
- Research Organizations. There are many organizations in the Great Lakes region that deploy sensors and collect and publish data from those sensors. Some of the data are also passed on to the GLOS or to other existing agency DMAC nodes. Examples include the University of Michigan's Ocean and Coastal Engineering Laboratory, the University of Minnesota-Duluth's Large Lake Observatory, and NOAA's Great Lakes Environmental Research Laboratory. These organizations typically maintain their own DMAC infrastructure.
- Canadian DMAC. Canadian agency data collectors and publishers were included on the list for completeness. Representatives identified through the Canadian Group on Earth Observing and speaking to water level, ice cover, water quality, and meteorology were contacted to identify DMAC infrastructure in place to handle these types of information.
- Other. Additional state and local activities were identified and contacted.

4.2 IOOS SUBSYSTEMS

The IOOS Implementation Plan generally suggests the following: a focus on system engineering that will meet the task required, continued planning and management to allow for adjustments and amendments to original plans, and coordinated regional activities that support the larger effort.

The initial IOOS implementation plan and the program itself focused on a number of discrete components or sub-systems, the Observing Sub-System, the Data Management and Communications Sub-System, the Modeling Sub-System and an Education component.

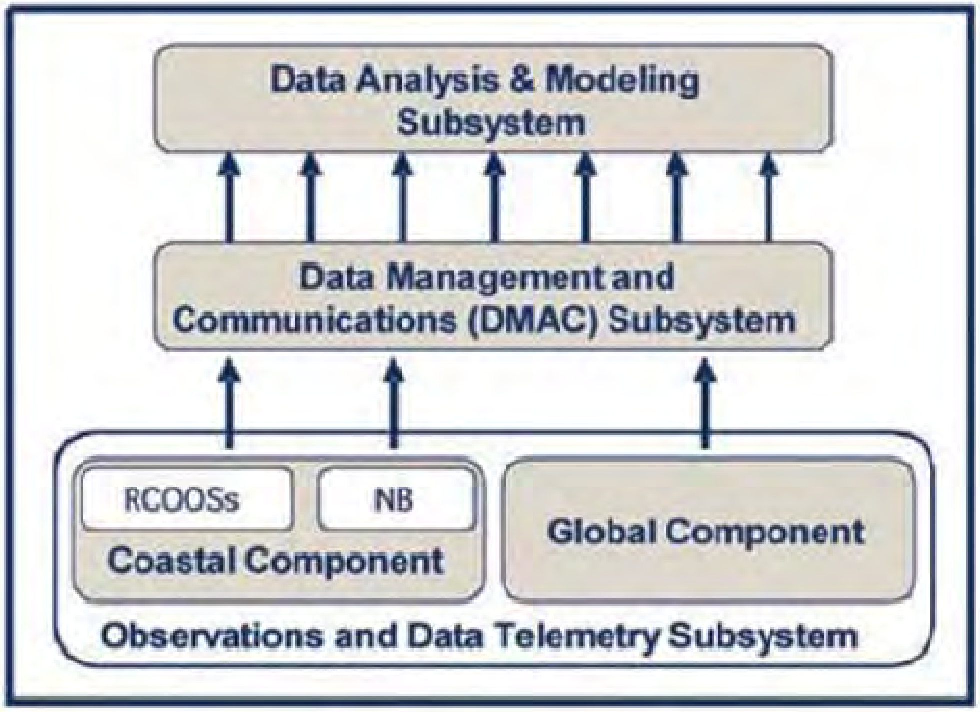


Figure 3. IOOS Component Schematic (courtesy NOAA IOOS)

The observing subsystem consists of global and coastal components with the latter broken down into a National Backbone (NB) for the Nation's Exclusive Economic Zone (EEZ) and Regional Coastal Ocean Observing Systems (RCOOSs) to address regional and local needs. The integrating engines are the DMAC and modeling subsystems. The NB provides data and information required by federal agencies and most, if not all, Regional Associations. RCOOSs contribute to the NB and are tailored to the data and information needs of each region.

IOOS defined their Data Integration Framework (DIF) which they are actively implementing through the establishment of the technical infrastructure, standards, and protocols needed to improve delivery of these seven initial "core ocean observation variables":

- Sea Temperature
- Salinity
- Water/Sea level
- Currents
- Ocean color

Findings of interest include:

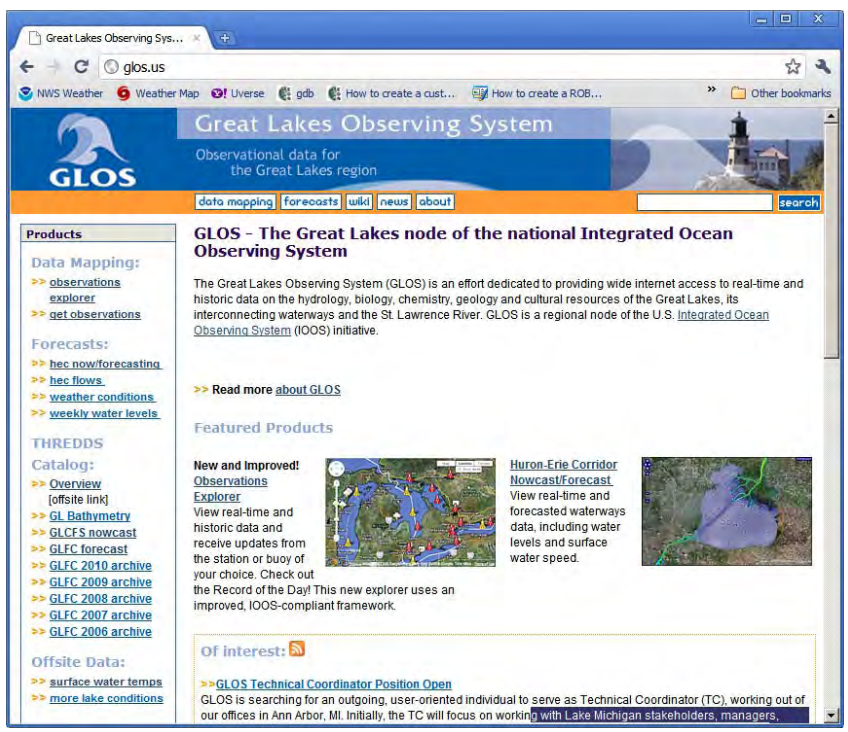
- Complete, integrated DMAC infrastructure is not currently in place for the Great Lakes.
- Existing DMAC for the Great Lakes is expressed as a combination of GLOS, national data services, and research operations.
- The current GLOS website has limited DMAC capabilities and builds instead on external DMAC infrastructure (e.g. linking to NDBC)
- There is interest in being delivered a “cookbook” solution that provides step-by-step instructions for assembling a DMAC node using (preferably) COTS approaches.
- Much data is available through multiple portals
- Data owners expect to provide their own QC and storage/archiving.
- Data owners are aware of many existing DMAC nodes such as NDBC, and find it appropriate to replicate their data to these nodes for redundancy in storage and access.
- Many expect to tie their data streams into GLOS, NDBC, and/or other existing DMAC nodes once sensors are fully operational and funded.

3. GLOS/GLC

The GLOS IOOS node provides access to realtime or near-realtime weather, water level, buoy and ship data throughout the Great Lakes. The GLOS website at www.glos.us, maintained by the Great Lakes Commission (GLC), serves these requests by linking to datasets managed and stored elsewhere, particularly at the NOAA National Data Buoy Center. Certain requests are routed to other Great Lakes organizations, either because of quicker access or of unique status. For example, data for the buoys maintained by the University of Michigan's Ocean and Coastal Engineering Laboratory is available from NDBC, but the GLOS website links directly to University of Michigan servers to access this data. Also, GLOS retrieves model forecast results directly from NOAA-GLERL, as this is the only source.

There is currently only one significant data management activity being implemented at the GLOS. This is the archiving of GLERL model forecast and nowcast results for historical purposes. GLOS and GLC staff anticipate that increased GLOS-sponsored buoy deployments will require development of complete DMAC capabilities to support downloading and QC of data as well as its aggregation and storage for eventual transmittal to NDBC as well as immediate sharing through GLOS website portals. Staff also expects to host results from additional important models identified in previous surveys and assessments as well as new products such as the GLOS/MTRI chlorophyll/DOC/minerals analysis based on MODIS data.

Short-term improvements to DMAC aspects of the site are currently limited to installation of improved data archiving and backup capabilities. Additional server capacity to handle DMAC operations for new sensors, and development of redundant/failover capabilities, are expected concerns as GLOS considers higher-profile services such as real-time navigation assistance.



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4. FEDERAL AGENCIES

Significant operational monitoring of the Great Lakes is performed by a number of Federal agencies, including the National Oceanic and Atmospheric Agency (NOAA), the United States Geological Survey (USGS), the National Aeronautics and Space Agency (NASA) and the Environmental Protection Agency (EPA). This section discusses nationwide programs administered by these agencies that include a footprint in the Great Lakes.

DMAC components operated by these agencies in support of national programs are assumed to be available for access to the observational data in the future in future versions of the GLOS, but are also assumed to be unavailable for use as GLOS building blocks. However, technology used in these components may provide a basis for design of the future GLOS.

4.1 NOAA

Three national NOAA programs were identified that provide data management and communications for observations collected in the Great Lakes:

- National Data Buoy Center (NDBC). NDBC delivers hourly observations from buoys and C-MAN stations nationwide, and currently serves up data from 45 C-MAN stations and nine buoys in the Great Lakes. The GLOS data portal provides access to this data in parallel with the NDBC website.
- Center for Operational Oceanographic Products and Services (CO-OPS). CO-OPS monitors, assesses, and distributes tide, current, and water level data from around the nation, including 27 Great Lakes water level stations.
- National Weather Service (NWS). NWS collects and manages data from 117 Automated Surface Observing System (ASOS) stations around the Great Lakes in the US and Canada, and from eight additional stations.

In addition, the Telecommunication Operations Center in the Office of the Chief Information Officer manages a number of services that support the NWS Telecommunication Gateway, including the NOAAport system for one-way near-real time broadcast of NOAA environmental data and products. NOAAport is used for transmittal of NWS data.

4.2 USGS

The USGS also operates a wide range of national programs that collect Great Lakes operational data:

- National Water Information System (NWIS). NWIS provides real-time streamflow, groundwater levels, and water quality sensor output in tributaries throughout the Great Lakes watershed.
- National Stream Quality Accounting Network (NASQAN) and National Water Quality Assesment (NAWQA) Program. NASQAN and NAWQA data have been collected at various locations in the Great Lakes to support water quality evaluations.

- Global Visualization Viewer (GloVis) and EarthExplorer. GloVis and EarthExplorer provide access to satellite products, including Aster, EO-1, Landsat, and MODIS.

Under the GLRI, USGS intends to carve out a Great Lakes "view" from its national realtime sensor networks for water. USGS is extremely interested in developing this Great Lakes view and evolving it to effectively interface, integrate and/or interoperate with the GLOS going forward.

4.3 NASA

NASA's OceanColor program includes the Great Lakes in its scope, serving up imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) satellites. These are used to provide quantitative data on global water bio-optical properties and can support estimates of chlorophyll-a and other water quality parameters.

4.4 EPA

The Environmental Protection Agency (EPA)'s major investments in data infrastructure are focused on the legacy Storage and Retrieval Data Warehouse (STORET) and the successor Water Quality Exchange (WQX). These databases cover the entire range of water quality data, but are generally highly scattered in time and space and not real-time. EPA's Great Lakes Environmental Database (GLENDA), focused on archiving and dissemination of results from the Lake Michigan Mass Balance Study and other projects, is available through EPA's Central Data Exchange (WQX is part of CDX).

5. RESEARCH ORGANIZATIONS

A number of organizations have deployed sensors on the Great Lakes for research purposes and collect and manage the sensor data for dissemination through their own web sites. The data are sometimes also made available through the GLOS website or NOAA-NDBC. The activities of each of five research organizations contacted for this review are briefly summarized, and relevant observations relevant to DMAC are listed as well.

In general, no details were collected on communications link, transmission and storage protocols, or hardware. The representatives contacted all indicated their willingness to provide additional details upon request.

5.1 UM OCEL

The University of Michigan (UM) Ocean and Coastal Engineering Laboratory (OCEL) performs remote measurements of ocean surface processes on both saltwater and freshwater. Observation platforms include a number of buoys on the Great Lakes; OCEL also provides operational support for buoys deployed by the Michigan Tech Research Institute (MTRI).

- Data are called in every ten minutes by cell phone.
- Data are first stored on a UM server, available to public through portal
- UM performs QC annually, dropping obviously bad points.
- Data are also sent to GLOS, which essentially keeps a mirror; however, the nature of GLOS QC on these data are unknown.
- Data are also sent to NBDC. However, NDBC currently stores only observations on the hour.

5.2 UMD LLO

The Large Lakes Observatory (LLO) at the University of Minnesota-Duluth (UMD) currently operates one meteorological buoy in Lake Superior.

- Data are collected every 10 minutes and transmitted hourly to shore by cell phone. The underlying software is LoggerNet.
- Raw data are archived on-site on two separate systems.
- LLO website provides time series graphs often used by fishermen and wind surfers
- The data are also provided to the UMD Natural Resource Research Institute, which provides its own, separate portal.
- A link to the raw data has been made available to GLOS and some other users.
- LLO’s buoy data will probably be made available through NDBC in 2011. The buoy deployment was viewed as experimental/shakedown until now, not operational.

- Operations are somewhat staff-limited. LLO plans to hire in a technician to implement more rigorous operational and data management procedures.

UMD LLO also operates an Autonomous Underwater Vehicle (AUV) in glider format as as a research project. The glider is deployed for up to two weeks, reporting back pressure, temperature and conductivity every 3-4 hours using Iridium. Data are collected every 1-2 seconds during the downward zig of each dive. DMAC for this new capability is somewhat ad-hoc for now.

5.3 UWM WATER

The University of Wisconsin-Madison (UWM) Great Lakes WATER (Wisconsin Aquatic Technology and Environmental Research) Institute operates buoys in Lake Michigan in the vicinity of Milwaukee.

- Data collected by radio telemetry then stored locally.
- Data are published through a UWM portal: http://www.waterbase.glwi.uwm.edu/index.php
- The buoys will eventually be connected to the GLOS, but are not yet considered fully operational by UWM WATER
- QC operations are expected to remain in-house.
- UWM WATER also maintains an archive of data collected by the Milwaukee Metropolitan Sewer District, and the Linnwood water purification plant. The data are entered manually, then made accessible at the same portal

5.4 SUNY ESF

The State University of New York (SUNY) College of Environmental Science and Forestry will be placing buoys near Oswego, Buffalo, and Rochester in conjunction with GLOS as part of the New York Great Lakes Research Consortium (NYGLRC). These installations will be very similar to the buoys deployed by ESF in Lake Oneida for the past three years.

- Buoy links have moved from radio to cellular phone.
- Buoy sensor package includes biochemical parameters – emphasis placed on understanding plankton activity. Lake Oneida installation included chlorophyll and phycocyanin sensors.
- Novel sensors call for alternative QA/QC process, including biweekly visits to buoys to collect field samples for ground truthing.
- Buoy and weather station also in place on St. Lawrence River near Governor’s Island biological station.
- Data served up through the NYGLRC Web Portal

5.5 NOAA-GLERL

NOAA’s Great Lakes Environmental Research Laboratory (GLERL) operates a number of pier-based meteorology stations and several buoys, and provides ice cover observations and short-term lake condition forecasts.

- Pier-based meteorology station observations – wind speed, temperature, etc., are passed on to NDBC for archiving and dissemination.
- Because of limited staff and funding, GLERL buoys are not yet on NDBC.
- Ice cover and forecasts available through GLOS using a THREDDS server, and NETCDF files respectively.
- Copies of all model results and monitoring data are stored locally at GLERL, archived in ASCII format.

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6. CANADIAN DMAC

Because of the binational nature of the Great Lakes, efforts were made to collect information about existing DMAC infrastructure operated by Canadian entities. Four subject areas were identified through the US-Canada Group on Earth Observations, Great Lakes Testbed – a demonstration project of the Group on Earth Observations (GEO), a voluntary partnership of governments and international organizations. The Great Lakes has been chosen as one of the first Testbed sites that will support the coordination of binational observing efforts between Canada and the United States and serve as a proving ground demonstrations for building international interoperable observing systems, where countries collaborate together to determine what is needed to promote the convergence of observation networks, systems and sensors.

Detailed information was provided for Canadian lake level and weather measurements; water quality was indicated to be very limited in coverage. No information was gathered on ice cover.

An additional source of metadata that may be incorporated is the Binational Monitoring Inventory maintained by US EPA and Environment Canada "to provide a single window on joint Great Lakes programs." This inventory supplies a valuable catalog of available data sets that may provide DMAC insight

6.1 LAKE LEVELS

Lake levels are collected at 34 gages throughout the Great Lakes by the Hydrographic Service, part of Fisheries and Oceans, Canada.

- Water levels are measured every three minutes at each gage.
- Data are QC'd/validated daily; hourly measurements are posted each day to the website. Website holds current and preceding month's data.
- Full datasets are sent to QC/validation, then post hourly data to website, send full data to Integrated Science and Data Management (ISDM), another Fisheries and Ocean office.
- Website holds current and previous months
- Monthly means are published in collaboration with USACE/NOAA.
- ISDM archives met, wave, tide and water data collected via NESDIS and GOES. Environment Canada acts as a Data Assembly Center for these data.
- ISDM staff are very interested in learning more about technology NOAA deploys to disseminate data.

6.2 WEATHER

Weather data are collected by Environment Canada from Offshore Data Acquisition Systems (ODAS) buoys deployed around the Great Lakes.

- Data from ODAS buoys are transmitted using GOES to Wallops Island downlink.

- Waves
- Surface Currents

The target for IOOS DIF was that at least four of the Regional Associations would be able to deliver these seven core variables using "IOOS standards". An assessment of this is available in the "DIF Assessment Report", November 2010.

The complete set of core variables consists of the following:

1. Acidity (pH)
2. Partial pressure of carbon dioxide (pCO2)
3. Bathymetry
4. Pathogens
5. Bottom character
6. Phytoplankton species
7. Colored dissolved organic matter
8. Salinity
9. Contaminants
10. Sea level
11. Dissolved nutrients
12. Stream flow
13. Dissolved oxygen
14. Surface currents
15. Fish abundance
16. Surface waves
17. Fish species
18. Temperature
19. Heat flux
20. Total suspended matter*
21. Ice distribution
22. Wind speed and direction*
23. Ocean color
24. Zooplankton abundance
25. Optical properties
26. Zooplankton species

In 2010, IOOS defined that "IOOS partners must demonstrate how the DMAC Subsystem component will be implemented and sustained based on the following guiding principles:"

A summary of these guiding principles are listed below - full text is available from:

Guidance for Implementation of the Integrated Ocean Observing System (IOOS®) Data Management and Communications (DMAC) Subsystem NOAA IOOS® Program Office White Paper (v1.0) March 12, 2010*

a) **Open Data Sharing**: IOOS®, being a part of the Global Earth Observing System of Systems (GEOSS), ascribes to the GEOSS data sharing principles.

b) **Provision of Data to WMO GTS**: The World Meteorological Organization (WMO) Global Telecommunications System (GTS), and an emerging next generation system - the WMO Information System (WIS), - disseminates data in near-real-time to operational weather and ocean forecasting centers. (A brief description of GTS is provided below)

c) **Service-Oriented Architecture (SOA):** DMAC employs a service-oriented architecture (SOA).

d) **Recommended Data Access Services**: The basic data access services currently used by IOOS® DMAC are listed below:

   • OPeNDAP Data Access Protocol (DAP) and/or Open Geospatial Consortium (OGC) Web Coverage Service (WCS) for access to gridded data and model outputs (for example a THREDDS data server

- Computers on west coast process into climate products
- Products go out and are sold on the Global Transmission System

7. OTHER

During the gathering of information, a number of additional observation resources were identified that may either provide models for DMAC development or provide examples of datasets that require additional consideration in design of DMAC.

7.1 AMERICAVIEW

AmericaView (AV) is a nationwide partnership of remote sensing scientists who support applied remote sensing research, K-12 and higher STEM education, workforce development, and technology transfer. AmericaView, the outgrowth of the 1998 OhioView pilot project designed to improve access to LandSAT data, includes members in most of the Great Lakes states.

- OhioView - the initial AmericaView site – developed effective home-brew infrastructure for acquisition, storage and dissemination of LandSAT data.
- Since EROS data became free, OhioView consists mostly of links to national data repositories/sources
- OhioView is concerned with challenges of finding and then stitching together necessary information. Processing time is an issue.
- WisconsinView has primary responsibility for MODIS imagery with multiple downloads daily. Strong expertise in satellite/remote sensing - data provider, internetworking, interoperability, standards-based computing, GLIN GeoServer is an example installation that provides additional value-added
- WisconsinView is working on delivery to mobile devices – Ipad/IPhone/Android. Tiling schemes are of high interest.

7.2 COASTWATCH

The NOAA CoastWatch program provides a variety of environmental data (i.e. SST, ocean color, winds, etc.) from several different satellite platforms covering all U.S. coastal waters, including the Great Lakes. Sea surface temperature maps support meteorological weather predictions and also support commercial and recreational activities (e.g., fishing), while color radiometry data and derived chlorophyll-a and total suspended matter/turbidity identify runoff plumes and blooms and also predict HABs.

The Great Lakes Regional Node, managed by NOAA-GLERL, provides a good example of a working portal to satellite, forecast models, and meteorological fata.

7.3 MISCELLANY

BeachGuard. Many Great Lakes states have implemented beach monitoring and notification programs with the support of the EPA BEACH Act. These data are available through online portals such as the Michigan, Indiana, and Illinois BeachGuard sites.

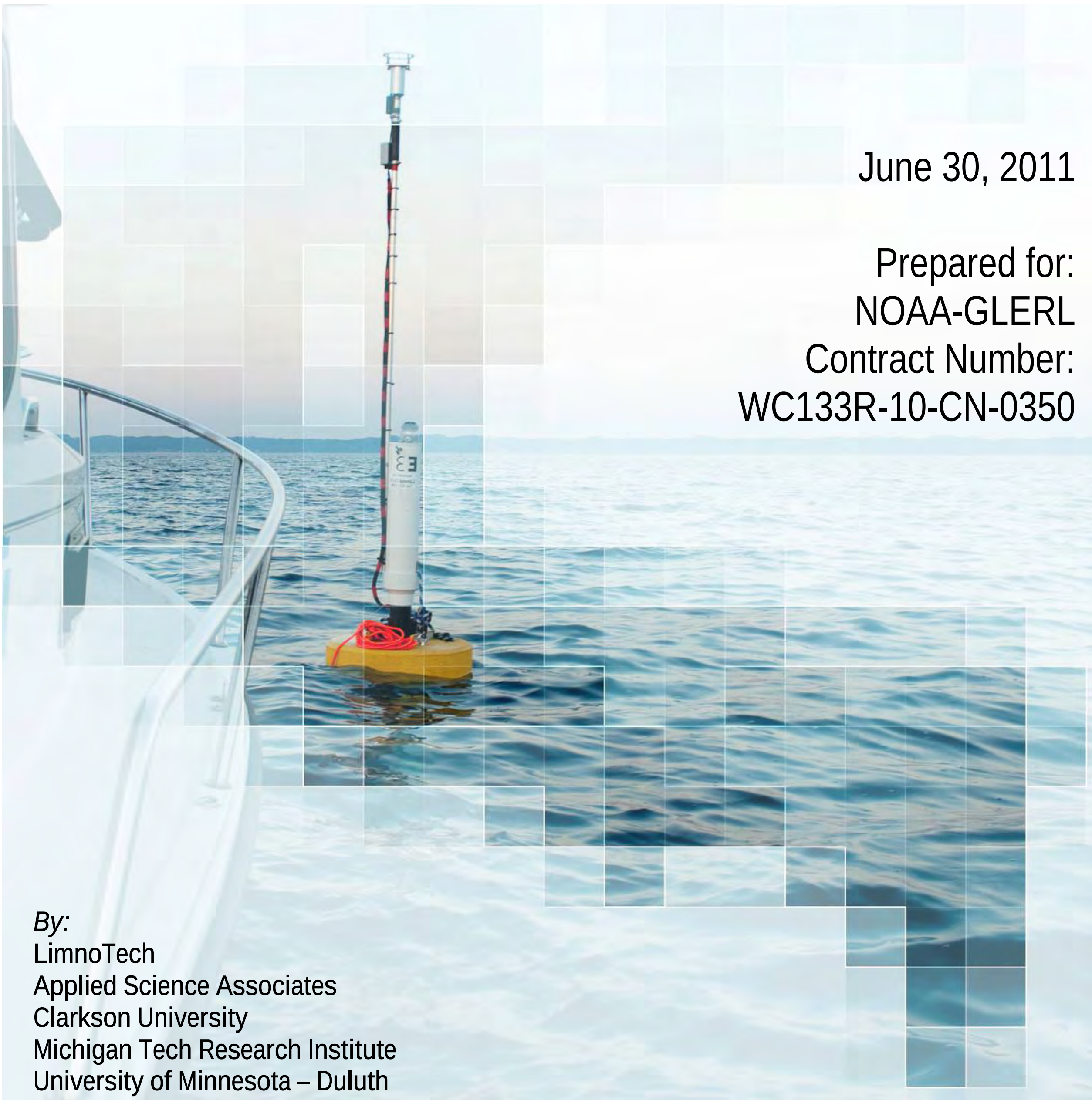
Fish and fisheries. Commercial catch data for the Great Lakes are available on-line from the USGS Great Lakes Science Center. Water quality data may also be collected by fisheries managers and researchers, including the Great Lakes Indian Fish and Wildlife Commission. Efforts are also underway to incorporate station and tag information from the Great Lakes Acoustic Telemetry Observing System into the existing GLOS website.

Mining activity. Though not directly operational, collections of data about mining activity on Lake Superior have implications for the Lake Superior LAMP, as mining can directly affect water quality.

Additional models. Data products that may need to be considered in DMAC design include The Nature Conservancy's ecological flows; USGS estimates of monthly inflows at ungaged stations; USGS SPARROW watershed model.

TECHNICAL MEMORANDUM 5: SUMMARY OF GREAT LAKES MODELS, SCALE, AND APPLICABILITY

Near-Term Design of the Great Lakes Observing System Enterprise Architecture



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SUMMARY OF GREAT LAKES MODELS, SCALE, AND APPLICABILITY
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LIST OF TABLES

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1. INTRODUCTION

This memo is the fifth technical memo in a series of six that summarizes the current observation systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six technical memos cover the following topics:

1. Current state of data management in support of observing systems
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Each of these technical memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

1.1 OBJECTIVE

The purpose of this memo is to document models that have been applied within the Great Lakes region that have the potential to become operational if they can support a portion of the goals of the Great Lakes Observing System. This memo provides the necessary background to make informed decisions concerning the incorporation of models into the enterprise architecture.

1.2 SCOPE

The models investigated as part of this project are limited to models with applications in the open waters of the lake, embayments, connecting channels, major tributaries, and watersheds that drain to the Great Lakes. Only models that have been applied in the previous ten years were considered for inclusion in this investigation; however some models can trace their origins prior to this cut off. The goal was to include the most recent model within a given model category.

1.3 APPROACH

This memo is divided into four major sections that include an introduction, discussion of operational models, listing of models by geographic scale, and references. The second section, discussion of operational models, defines what is meant by the term “operational” and lays out the components that are necessary for a model to be considered operational. In the third section, all of the models reviewed as part of this memo are summarized by geographic area.

• OGC Sensor Observation Service (SOS) for access to in situ observations (e.g., observations at a point, profiles, trajectories, etc.);

• OGC Web Map Service (WMS) for access to georeferenced image data; and

• Other service types, in particular for event-based or bulk subscriptions, are under consideration.

e) **Common Data Formats**: IOOS® DMAC has selected several preferred data formats, and is researching others in an effort to maximize usefulness. IOOS® partners are expected to offer data in IOOS® formats (legacy formats may also be maintained, if desired). Formats currently in use include:

• Binary format for gridded data: Network Common Data Format (NetCDF) with Climate and Forecast (CF) conventions;

• Text format for in situ data: comma-separated value (CSV) with CF and IOOS-specific conventions; and

• XML format for in situ data: Open Geospatial Consortium (OGC) Geography Markup Language (GML) with IOOS application schema.

f) **Common Vocabularies and Identifiers**

g) **Metadata**: Descriptive information about datasets, sensors, platforms, models, analysis methods, quality-control procedures is essential for the long-term usability and reuse of information.

h) **Storage and Archiving**: IOOS® partners must describe how they will:

• Provide initial stewardship; and

• Ensure permanent archiving of their observations, model outputs, metadata and derived information products of archival quality.

i) **Data Management Planning and Coordination**: IOOS® partners should maintain the capacity to and demonstrate how they will stay involved and coordinated with national and regional activities.

j) **IOOS Maturity Levels and Certification Standards**.

k) **Consideration for Long-term Operations**.

Following this report, in November 2010, the IOOS Office issued a comprehensive paper "U.S. Integrated Ocean Observing System: A Blueprint for Full Capability, Version 1.0" and this goes on to describe in detail the evolution of the regional observing systems with defined steps to reach full system capability (FC). The report describes high level components of U.S IOOS called nodes, summarized as:

- **Platforms, sensors, and observations**. This logical node encompasses all observing systems (in situ and remote), platforms, sensors, human observations, and others that collect observing data from and about the oceans and report their data to a U.S. IOOS DMAC-compliant DAC (Data Assembly Center).

1.4 GREAT LAKES MODEL INVENTORY

Most of the model descriptions in this memo are drawn from the Great Lakes Model Inventory completed by LimnoTech for GLOS in 2009. The inventory is intended to be turned into an online repository for Great Lakes Researchers and kept up-to-date through user submissions. The database can be accessed at http://www.glos.us/glosmi/pub/ . A complete listing of the models in the inventory is attached as Appendix A.

2. OPERATIONAL MODELS

As described in the approach section above, this memo is designed to document existing environmental models that have been applied within the Great Lakes basin. Some of the models are currently running in an operational mode, which means they are digesting input data in near real-time and producing either hindcasts or forecasts using those inputs. These types of models have the most value for an observation system, because they can be used as decision support tools that operate in near real-time. The majority of the models described in this memo are not operational models, however some of them could be utilized in a near real-time/ operational format if required. This memo will document both operational and non-operational models.

Operational models have several characteristics that separate them from other research models. Below is a listing of several of these characteristics.

1. Near real-time link to input data from either in-situ observations or other model predictions.
2. Regular reporting and post processing of model results.
3. Reasonable support mechanism to maintain operation.

These are basic requirements of models that are considered real-time or operational. Before a model is made operational it is assumed that the developers have initially calibrated the model to report results that meet the end user needs. Calibration can continue to occur while the model is operational and users can even be made aware of the current calibration status, but directly displaying model predictions and data observations of simulated parameters.

The Great Lakes Coastal Forecasting System (GLCFS), developed by NOAA-GLERL, is a good example of an operational model. The model framework was developed and calibrated as part of several research projects. In the late 1990s an effort was made to operationalize the individual models for each Great Lake. NOAA meteorological forecasts provide input data for forecast simulations, while real-time links to in-situ observations of meteorological conditions provide the input data for hind cast (now cast) simulations. Model output is post processed and diseeminated via a public website. A companion model (GLOFS) operated at the NOAA Center for Operational Oceanographic Products and Services (COOPS) provides model output to NOAA forecasters.

With respect to an observation system, real-time models provide tools that users can use to make near real-time decisions. Other models have value for the observation system as they can be used to simulate longer periods (e.g. monthly, quarterly, or annual periods) that are unfeasible for operational models. The operation of other models can be streamlined so that results are reported on a regular basis, but don’t have true links to real time data and require more user interaction.

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3. MODELS BY SCALE

3.1 GREAT LAKES SCALE MODELS

The models listed in this section have been applied throughout the Great Lakes basin and while some of them are currently operational many are research models that could be made operational if needed.

3.1.1 Great Lakes Coastal Forecasting System (GLCFS)

The NOAA-GLERL lab maintains operational models of every Great Lake to provide real-time information and forecasts of temperatures, currents, water levels, and waves. Nowcast (present to 48 hours in the past) and forecast (present to 120 hours in the future) results are available online at http://www.glerl.noaa.gov/res/glcfs/ .

The nowcast simulations use surface winds and air temperature data from a variety of observing platforms around the Great Lakes. The different observing systems include National Weather Service (NWS) surface airways stations at airports, Coastal-Marine Automated Network (CMAN) stations, NOAA-GLERL mesonet stations, National Ocean Service's water level stations, and US and Canadian buoys deployed in the Great Lakes. The real-time observations are provided by the NWS National Centers for Environmental Prediction (NCEP). Surface water temperature data is also obtained from the NOAA-Coastwatch Great Lakes Surface Environmental Analysis (GLSEA) to compute stability of the atmosphere over the lakes.

The forecast simulations are forced by surface wind and air temperature forecasts from the NWS North American Mesoscale (NAM) weather forecast model. The NAM operates at a spatial and temporal resolution of 12km and 3hours, respectively. These forcings are interpolated over the model grid for each lake and interpolated to a time resolution of 3 hours.

A summary of the model grids for each model is presented below in Table 1. The models were developed and refined over the past ten years and are meant to serve a broad user base that includes National Weather Service forecasters, boaters, and water quality managers. A model of Lake Erie was operational in 1997 and the rest of the Great Lakes in 2002. The version of the model housed at NOAA-GLERL is considered a research version of the operational model and is used to test new products and model improvements (such as increased grid resolution).

In recent years local water quality issues required the development of a finer resolution hydrodynamic model near Burns Ditch (Indiana), Grand Haven (Michigan), and Saginaw Bay (Michigan). The finer resolution models are driven by forcings from the larger whole-lake model and the grids are summarized at the bottom of Table 1. Each of the study areas is influenced by a nearshore tributary that can greatly impact the water quality of the nearshore areas (primarily beaches).

Table 1. Summary of model grids used in the GLCFS

Water Body	Grid Size (km)	# of Cells	Layers
Superior	10	807	20
Michigan	2	14,458	20
Huron	2	14,733	20
Erie	2	6,436	21
Ontario	5	746	20
St. Clair	0.5	4,444	
Nested Grids			
Burns Ditch	0.1	11,982	11
Grand Haven	0.1	13,133	20
Saginaw Bay	0.2	38,864	11

3.1.2 Great Lakes Operational Forecasting System (GLOFS)

The Center for Operational Oceanographic Products and Services (CO-OPS) maintains an operational version of the model that is specifically designed to meet the needs of weather forecasters. The model grid used is simpler (minimum resolution of 5 km) and only includes the five Great Lakes. Model predictions are updated four times per day. More information about this model is available online at http://tidesandcurrents.noaa.gov/ofs/glofs.html

The model predictions from the operational model are quality controlled by the Continuous Operational Real-Time Monitoring System (CORMS), which is maintained by CO-OPS. This system provides round the clock monitoring and quality control of sensors and data in order to ensure the quality of data used by weather forecasters.

3.1.3 Large Basin Runoff Model (LBRM)

NOAA-GLERL developed a large-scale operational model in the 1980s for estimating rainfall/runoff relationships on the 121 largest watersheds surrounding the Great Lakes. The model is physically based and is calibrated systematically. Daily precipitation, temperature, and insolation (the latter available from meteorological summaries as a function of location) may be used to determine snow pack accumulations, snow melt (degree-day computations), and net supply. The net supply is divided into surface runoff, and infiltration into the upper soil zone. Percolation into the lower soil zone, evapotranspiration, and interflow are all tracked. A schematic of the mass balance is shown below Daily model predictions are used for a variety of studies, including hydrological forecasting in GLERL's Advanced Hydrologic Prediction System, which gives probabilistic outlooks of Great Lakes evaporation, runoff, and lake levels, among others. Uses also include past studies of climate change impacts on Great Lakes hydrology, and several analyses of management and regulation scenarios. More information about the model is available at http://www.glerl.noaa.gov/res/Programs/pep/dlbrm/home.html .

3.1.4 Great Lakes Advanced Hydrologic Prediction System (AHPS)

The Advanced Hydrologic Prediction System (AHPS) is maintained in an operational state by NOAA-GLERL to facilitate the prediction of total inflow, outflow, mean lake level, and 22 other hydrology variables over the 121 watersheds and 7 lake surfaces of the Great Lakes basin. For each water body the model produces an 18 month hindcast and a 9 month forecast/outlook. The primary purpose of the model is to inform a coordinated committee that releases monthly updates on water level trends in the Great Lakes. The system incorporates both current conditions, antecedent to a forecast, and multiagency, multi-area, multi-period climate outlooks of meteorology probabilities. Extended water level forecasts are evaluated over three periods to determine the value of antecedent conditions and meteorological outlooks in making them. While the use of antecedent conditions adds considerably to Great Lakes forecasting ability, the use of existing meteorological outlooks adds little. GLERL's AHPS appears better than, or as good as, other Great Lakes forecasts and offers the advantage of improvement as better near real time data streams and improved process models become available. More information about the AHPS is available online at http://www.glerl.noaa.gov/wr/ahps/curfcst/curfcst.html

3.1.5 Advanced Hydrologic Prediction Service (NWS)

The Advanced Hydrologic Prediction Service (AHPS) provides new information and products provided through the infusion of new science and technology. This service improves flood warnings and water resource forecasts to meet diverse and changing customer needs. AHPS provide forecasts of river levels and river flow volumes from an hour to a season for areas large and small, including river forecast information such as:

- How high the river will rise
- When the river will reach its peak
- Where property will be flooded
- How long flooding will continue
- How long a drought will last

AHPS river, flood and drought forecasts are prepared by hydrologists and hydrometeorologists at the NWS's 13 River Forecast Centers and 122 Weather Forecast Offices. AHPS reduces loss of life and property, mitigates flood damages (three fourths of all Presidential Disaster Declarations involve flood damages), leads to a savings of over $760M per year, and significantly improves NOAA's capability to respond to prevalent challenges with energy production and water resource stewardship. More information is available online at http://www.nws.noaa.gov/oh/ahps/.

3.1.6 Coupled Hydrosphere-Atmosphere Research Model (CHARM)

Previous work at GLERL (between 1989and 2005) was undertaken to evaluate the impact of greenhouse warming on the water budget of the Great Lakes Basin. Such studies included one-way coupling of the lakes and land to a proxy of the atmosphere created by simple manipulation of the output from general circulation models with global domains and no resolution of the Great Lakes at all. As a result of the lack of realistic surface-atmosphere feedback under this scheme, the Coupled Hydrosphere-Atmosphere Research Model (CHARM) was developed to enable an assessment of the impact of greenhouse warming on the Great Lakes region. The model allows simulated lakes to directly feed back into the atmosphere through exchange of heat and moisture, while fully accounting for runoff from land surfaces. A new version of the Coupled Hydrosphere-Atmosphere Research Model (CHARM) was developed in 2005. This uses as its basis version 4.4 of the Regional Atmospheric Modeling System (RAMS), compared to version 3a in the previous CHARM.

3.1.7 GLMOD

GLMOD is a physically-based, multi-media model being developed to support the assessment and management of chemicals of emerging concern in the Great Lakes basin {LimnoTech 2009}. It is initially being designed as a screening level model to compare the potential exposure pathways and risks of emerging chemicals in the Great Lakes in order to prioritize and plan for source reduction. However, because it establishes a spatially and temporally explicit quantitative relationship between the sources, cycling, ultimate fate, and effects of these chemicals, it also will have the potential to assist in prioritizing research and monitoring programs for determining chemical properties, measuring sources, evaluating exposure pathways, evaluating trends, and identifying hotspots.

The GLMOD framework was field-tested and informally calibrated by configuring the model to represent the major features of the Great Lakes basin and developing a PCB hindcast simulation for the period 1980-1999. The approach undertaken for field testing the model involved reconstructing historical loadings of PCB congener mass via air emissions and watershed tributary loadings to the Great Lakes, as well as parameterizing various model process rates and coefficients. A recommendation of the developers of the model suggested that GLMOD could be linked CHARM to evaluate the impacts of forecasted climate change in the Great Lakes region on the exposure and effects of chemicals within the system.

3.1.8 High Impact Targeting

The HIT model can be used to estimate sediment loadings for sub-watersheds and also identify areas with high erosion potential (primary use thus far). The new model integrates three spatially-explicit components. First, an estimate of the percentage of erosion that results in sediment transported to nearby streams is obtained from the Spatially-Explicit Delivery Model (SEDMOD) and the Revised Universal Soil Loss Equation (RUSLE). Second, the actual annual volume of eroded soil is obtained from the Revised Universal Soil Loss Equation (RUSLE). Third, the annual volume of sediment transported to nearby streams is obtained from combining the results of SEDMOD and RUSLE.

The model has been applied to the whole Great Lakes basin. A study was recently completed to estimate sediment loadings for sub-watersheds in the Lower Maumee River Watershed in northern Ohio. Ten-meter DEMs were used to identify high risk areas where erosion will likely result in significant sediment loadings and associated water pollution. This high degree of resolution enables precise targeting of specific farm fields.

Challenges in moving ahead with the HIT system include when some data was generated and the comprehensive availability of some data. For example, the primary land cover layer (National Land Cover Dataset, or NLCD) used in the model is based on 1992 Landsat TM imagery. This data comes in relatively coarse 30-meter resolution instead of the more desirable 10-meter resolution. The primary soil data layer (derived from the USDA NRCS SSURGO database) has not been completed for the entire Great Lakes Basin. As a result, some areas must be modeled with much coarser STATSGO data. Finally, SEDMOD processing requires substantial CPU time. At a 10-meter resolution, large watersheds like the St. Joseph in southwest Michigan would take a computer with a 3-gigahertz processor and 1-gigabyte of RAM over a week to process.

3.1.9 Integrated Ecological Response Model

The Integrated Ecological Response Model (IERM) has been designed to compute and display the response of each of the Environmental Technical Working Group (ETWG) performance indicators to alternative water level and flow regulation plans being considered for the Lake Ontario-St. Lawrence River system. Limno-Tech, Inc. (LTI) and Environment Canada, in collaboration with ETWG researchers and modelers, is responsible for building the IERM and incorporating it as the environmental component of the Shared Vision Model (SVM). That transfer is being made by linking the executable version of the IERM, which is written in Visual Basic 6, to the SVM, which is encoded in STELLA and Microsoft Excel. The model domain, like all the interest group components of the SVM, includes the entire Lake Ontario system and the St. Lawrence River from the Lake Ontario outlet to Trois-Riviere, Quebec.

IERM was applied to the Lake Ontario - St. Lawrence (LOSL) system. A series of ecological sub-models were developed for the portion of the LOSL system above the Moses Saunders Dam, including Lake Ontario and the upper St. Lawrence River. For a variety of reasons, nearly all of the ETWG studies and associated data collection above the Moses Saunders Dam focused on Lake Ontario and the Thousands Islands region (IJC Shoreline Unit R1). However, performance indicator algorithms were developed to represent fish and wetland bird response in the upper St. Lawrence River below the Thousand Islands area (IJC Shoreline Units R2-R3) based on limited existing data.

A complete set of ecological performance indicators was developed to represent habitat supply and/or population response in each of the 3 regions for 6 indicator groups: wetland vegetation, fish species/guilds, wetland birds, herptiles (amphibians and reptiles), mammals, and species-at-risk. A specific metric (and associated units) was identified for each PI. The PI metric provides a means for measuring/computing the annual PI response. For example, fish habitat supply PIs were calculated as weighted suitable habitat area in hectares. The algorithms/metrics developed for each performance indicator were applied within the IERM to generate a time series of predicted annual scores for each regulation plan based on hydraulic outputs provided by the SVM.

3.1.10 Integrated Catchments Model for Carbon

The model is 1-dimensional and operates on a daily time step. It is semi-distributed and able to simulate both soil and surface water DOC processes in large and small catchments. The model has been modified from the original nitrogen focus of the INCA to include carbon. The model requires time series of air temperature and precipitation data for operation. It is calibrated against time series of DOC and flow. Spatial data on subcatchment areas and land cover are required.

The model has been applied to two headwater watersheds in Muskoka-Haliburton and two of the larger rivers draining into Lake Simcoe. It has been used to predict future surface water DOC concentrations in the Great Lakes Basin and the Nordic countries.

3.1.11 Rate Constant Model for Chemical Dynamics

The Rate Constant Model for Chemical Dynamics is a mass balance model that can be used to determine the fate of chemicals in the Great Lakes basin and elsewhere. The rate constant approach used in the model allows for the uniform and complete treatment of all processes. The model considers three compartments: the atmosphere, a single well-mixed water column, and a well-mixed surficial sediment layer. The contaminant sources considered include land-based discharges and atmospheric deposition. The quantified processes in the model included chemical degradation in the water column and sediment, outflow, sediment-water exchange, and sediment burial. A simple aquatic food chain model is also included. The model calculates the contaminant concentration in water and sediment. These concentrations are then used as input to the food chain model to compute concentration in the various organisms. The model was applied to predict transport and fate of organic contaminants in Lake St. Clair, Michigan.

http://www.trentu.ca/academic/aminss/envmodel/models/RateCon.html

3.1.12 Spatially Referenced Regressions on Watersheds

SPARROW (Spatially Referenced Regressions On Watershed attributes) is a watershed modeling technique for relating water-quality measurements made at a network of monitoring stations to attributes of the watersheds containing the stations. The core of the model consists of a nonlinear regression equation describing the non-conservative transport of contaminants from point and diffuse sources on land to rivers and through the stream and river network. The model predicts contaminant flux, concentration, and yield in streams and has been used to evaluate alternative hypotheses about the important contaminant sources and watershed properties that control transport over large spatial scales.

USGS scientists developed SPARROW (Smith and others, 1997) to (a) utilize monitoring data and watershed information to better explain the factors that affect water quality, (b) examine the statistical significance of contaminant sources, environmental factors, and transport processes in explaining predicted contaminant loads, and (c) provide a statistical basis for estimating stream loads in unmonitored locations.

The model estimates contaminant concentrations, fluxes (or “mass,” which is the product of concentration and streamflow), and yields in streams (mass of nutrients entering a stream per acre of land), and evaluates the contributions of selected contaminant sources and watershed properties that control transport throughout large river networks. It empirically estimates the origin and fate of contaminants in streams and receiving bodies, and quantifies uncertainties in these estimates based on coefficient error and unexplained variability in the observed data.

3.2 REGIONAL AND LOCAL SCALE MODELS

This section discusses models that are applied to a specific Great Lake or a portion of the lake.

3.2.1 Lake Michigan Basin

3.2.1.a POM: Grand Haven & Indiana Dunes

Traditional beach monitoring for E. coli typically requires a 24 hour incubation period, resulting in people unintentionally swimming in contaminated water, or conversely loss of local economic revenues and beach time. To address this issue, the GLERL-based Center of Excellence for Great Lakes and Human Health is working to understand the influence of wind, waves, surface temperature, and water currents on pathogen transport by conducting tests in the Grand River, a major tributary of Lake Michigan, to track contaminant flow downstream to Lake Michigan and its adjacent beaches.

The Great Lakes Forecasting System (GLFS, Bedford and Schwab, 1994; Schwab and Bedford, 1994) has been developed to provide short-range operational (regularly scheduled) predictions of such conditions for the open waters of the Great Lakes. Variables predicted include the three dimensional velocity field, the three-dimensional temperature field, the water level distribution and the wind wave height, length, period, and direction, and resuspension, transport, and deposition of bottom sediments based on wave and current conditions (Lou et al., 2000). The GLFS was used to help develop a model that would aide in predicting beach closures. Dye studies were performed and used to help develop this model. The model can predict the transport and distribution of contaminants from the Grand River into Lake Michigan. The model fairly accurately make estimates for E Coli concentrations near the lake shore in a 2 dimensional grid. Grid figures can be developed to show the contaminant dispersion and transport distance.

http://www.glerl.noaa.gov/res/glcfs/.

3.2.1.b EFDC: Southern Lake Michigan Shoreline Model

The EFDC model (Hamrick, 1992) solves the vertically hydrostatic, free-surface, variable-density turbulent- averaged equations of motion and transport equations for turbulence intensity and length scale, salinity, and temperature in a stretched, vertical coordinate system, and either a Cartesian or curvilinear- orthogonal horizontal coordinate system. Equations describing the transport of suspended sediment, toxic contaminants, water quality state variables, and E. coli may also be solved by EFDC. Input data to drive the EFDC model include open boundary water surface elevations, wind speed and direction, atmospheric thermodynamic conditions, open boundary salinity and temperature, volumetric inflows, and inflowing concentrations of E. coli, and E. coli decay rate. Model outputs include water surface elevation, horizontal velocities, salinity, temperature, and E. coli concentration.

www.in.gov/idem/tmdl_lakemich_report.doc

3.2.1.c MICHTOX: Lake Michigan

MICHTOX is a toxic chemical mass balance and food chain bioaccumulation model. The model can be used to provide a screening-level analysis of the potential future trends in total

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- **Data assembly centers**. This logical node includes Federal and non-Federal entities that have ocean observation data in accessible databases and that have adopted U.S. IOOS DMAC standards and passed U.S. IOOS certification (a process to be developed in accordance with the ICOOS Act of 2009). DACs (both existing and newly formed) will be registered in the U.S. IOOS registry. The heart of a DAC is the database that contains the observation data generated in the platforms, sensors, and observations node. DACs collect data from one or more sources and compile them locally so that metadata about the observations are captured and QC/QA processes can be applied.

- **Archives**. This logical node contains archives of ocean observations that were initially recorded at DACs, are DMAC compliant, and are in the U.S.IOOS registry.

- **DMAC data services**. Both DACs and archives store data in formats and structures that are conducive to the data's originally intended uses. This node organizes and packages the data to enable users/customers to easily find, access, and use data from various sources.

- **DMAC utility services**. This logical node contains the hardware and software to deliver value-added services that use U.S. IOOS data obtained from DACs, archives, or model/analysis outputs. Utility services entail registry, catalog for data discovery, mapping and visualization, system monitoring, format conversion, subscriptions and alerts, and data integration.

- **Client component.** This logical node contains client-owned, DMAC-compatible software that is uniquely configured to the user's system to access U.S. IOOS data, utility services, or model/analysis outputs. This software will accept the data feed from U.S. IOOS and render that data in a manner required by the U.S. IOOS customers' models and analytical tools to meet their data needs.

- **Models and analytic tools**. This logical node represents the users of U.S. IOOS data and utility services. It includes all the models, analytic tools, or other destinations for U.S. IOOS data, utility services, or model/analysis outputs.

- **R&D. U.S**. IOOS uses its robust communications with data providers (DACs, archives, and sponsored models) and data customers to identify R&D requirements; it then coordinates with R&D-capable entities to pursue research to meet those needs.

- **Training and education**.

- **Governance and management**.

polychlorinated biphenyl (PCB) concentrations in Lake Michigan water, sediment, and fish under a variety of contaminant load scenarios. Results of the MICHTOX modeling indicate that atmospheric exchange is a dominant loss process of total PCBs in Lake Michigan, and that the reservoir of total PCBs in the sediment has a significant impact on the future trends in concentrations of total PCBs in lake trout.

http://www.epa.gov/med/grosseile_site/LMMBP/lmmbp-pcb-report/p3-c1.pdf

3.2.1.d LM2: Lake Michigan

As one of the components in the overall Lake Michigan Mass Balance Project (LMMBP) modeling framework, a comprehensive polychlorinated biphenyl (PCB) congener-based water quality model, LM2-Toxic, was developed to simulate fate and transport of PCBs in both water and sediment of Lake Michigan. The main focus of this model was to address the relationship between sources of toxic chemicals and their concentrations in water and sediments of Lake Michigan, and provide the PCB exposure concentrations to the bioaccumulation model (LM2 Food Chain) to predict PCB concentrations in lake trout tissue.

LM2-Toxic is a revision of the United States Environmental Protection Agency (USEPA)-supported WASP4 water quality modeling framework. It incorporates the organic carbon dynamics featured in GBTOX and the sediment transport scheme, a quasi-Lagrangian framework, used in the IPX. Both GBTOX and IPX were WASP4-type models and major components in the Green Bay Mass Balance Project (GBMBP) modeling framework. Another important modification was the addition of updated air-water exchange formulations to the model.

http://www.epa.gov/med/grosseile_site/LMMBP/lmmbp-pcb-report/p4-c1.pdf

3.2.1.e GBTOX: Green Bay

GBTOX evaluates the chemical transport in surface waters in a temporal and spatial resolution by coupling several models including eutrophication, contaminant fate and transport, and food web models. This model can be used to quantify the ecological impacts of water withdrawals.

GBTOX was developed within the WASP4 modeling framework maintained and distributed by the EPA/CEAM. The model is temporally dynamic and spatial segmented in horizontal and vertical. The Model couples eutrophication, hydraulic transport model, sorbent dynamic, and food chain models. It conducts three separate mass balances: a water balance, an organic carbon sorbent balance, and a toxic chemical balance. Each balance includes specification of external inputs, internal sources and sinks, and system outputs. The hydraulic transport model provides the advective flows and bulk dispersion coefficients that drive the transport of all constituents among water column segments of the system. Sorbent model considers three state variables: biotic carbon (BIC), particulate detrital carbon (PDC), and dissolved organic carbon (DOC). The eutrophication model is used to determine autochthonous organic carbon loadings.

3.2.1.f LM3: Lake Michigan

LM3-Eutro was developed in conjunction with several other mathematical models as part of the Lake Michigan Mass Balance Project (LMMBP). These models work together to determine contaminant concentrations in Lake Michigan fish predators under present and future conditions. LM3-Eutro was based on the CE-QUAL-ICM model transport framework (Cerco and Cole, 1995) and used state-of-the-science eutrophication kinetics to simulate the interactions between plankton and nutrients. LM3-Eutro is a high-resolution framework containing 44,042 water column segments. The model is driven by the Princeton Ocean hydrodynamics Model (POM) (Schwab and Beletsky, 1998). A sediment model is under development. Until developed, LM3-Eutro includes user-defined fluxes to simulate sediment-water interactions. The model has 17 state variables, including a single zooplankton class, two phytoplankton classes, and several particulate and dissolved nutrient (including carbon) states.

http://www.epa.gov/med/grosseile_site/LMMBP/lmmbp-pcb-report/p2-c1.pdf

3.2.1.g GLPM: Great Lakes Primary Productivity Model

The Great Lakes Production Model (GLPM) estimates *in situ* integral daily production, accounting for diel variations in surface irradiance and depth variations in P-I parameters, algal biomass, and light extinction. The strength of the GLPM is that it accepts discrete measurements of biological and environmental parameters and generates a nearly continuous estimate of primary production in both space and time. In addition, by using a monte carlo approach, the model can be used to (1) predict the range of primary production estimates based on variance associated with certain input parameters, and (2) obtain estimates of primary production at sites where P-I parameters are not available.

ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-090/tm-090.pdf

3.2.1.h Great Lakes Cladophora Model: Nearshore Lake Michigan

The Great Lakes Cladophora Model takes a mass balance approach, in which two major phosphorus (P) pools (dissolved phosphorus and phosphorus stored in Cladophora) and biomass are calculated by simulating the gain and loss processes for each of these state variables. For dissolved P, the gain processes include loading and mass transport within the lake, while the loss processes are uptake by Cladophora and mass transport. For Cladophora P content, uptake is the main gain mechanism while dilution through growth is the loss process. This portion of the model accounts for the feedback between Cladophora P content and P uptake. P uptake is modeled as a function of dissolved P, stored P and temperature. For Cladophora biomass, growth is the gain processes, while losses result from respiration and sloughing. Growth is modeled as a function of light, temperature, stored P, and carrying capacity.

http://www.glwi.uwm.edu/research/aquaticecology/cladophora/pdf_workshop_prodeedings/Auer%2057%20to%2062.pdf

3.2.2 Lake Huron Basin

3.2.2.a DLBRM: Saginaw Bay Watershed

A physically based, spatially-distributed water quality model is being developed to simulate spatial and temporal distributions of material transport in the Great Lakes Watersheds of the U.S. The model, termed the Distributed Large Basin Runoff Model (DLRBM), was applied to the Saginaw Bay Watershed. Multiple databases of meteorology, land use, topography, hydrography, soils, agricultural statistics, and water quality were used to estimate nonpoint source loading potential in the study watersheds. Animal manure production was computed from tabulations of animals by zip code area for the census years of 1987, 1992, 1997, and 2002. Relative chemical loadings for agricultural land use were calculated from fertilizer and pesticide estimates by crop for the same periods. Comparison of these estimates to the monitored total phosphorous load indicates that both point and nonpoint sources are major contributors to the total nutrient loads in the study watersheds, with nonpoint sources being the largest contributor, particularly in the rural watersheds. These estimates are used as the input to the distributed water quality model for simulating pollutant transport through surface and subsurface processes to Great Lakes waters. Visualization and GIS interfaces are developed to visualize the spatial and temporal distribution of the pollutant transport in support of water management programs.

3.2.2.b Regression Load Models: Saginaw River

Saginaw River is the largest tributary of Saginaw Bay, Lake Huron. Over the years, high nutrient and sediment loads have led to the eutrophication of the bay. To tackle this problem, a target Total Phosphorus (TP) load of 440 metric tons/yr was established for Saginaw Bay, successfully diminishing eutrophication. However, algal blooms and nuisance algal beach deposits have recently returned to Saginaw Bay. Here we analyze a regression model developed to evaluate current loads using the few water quality measurements and daily discharge data available at a few points in the basin, determine the contributions of sub-watersheds to the total load, and quantify the impact of model and input uncertainty on the load figure reliability. The model takes into account the effect of discharge, rising and receding flood phases, previous storm‘s flushing, seasonality, and long term trends in pollution generation on Total Suspended Solids, TP, and Total Nitrogen concentrations. Results indicate that the model is able to track these dynamics well: correlation in daily concentration at the river outlet for 1998-2008 is 0.88, 0.84, and 0.75 respectively, while correlation in daily loads is above 0.95. Computation of Saginaw River‘s annual TP loads indicates that the target TP load of 440 metric tons has been met only during dry years.

3.2.2.c POM: Saginaw Bay

A 3-dimensional circulation model of Lake Huron is used to calculate lake circulation and thermal structure in 1992-1993 on a 2 km grid. The model is based on the Princeton Ocean Model (POM) of Blumberg and Mellor (1987). The hydrodynamic model of Lake Huron has 20 vertical levels with finer spacing near the surface and the bottom. Momentum and heat fluxes are derived from hourly observations obtained from meteorological stations around Lake Huron and NDBC buoys. Model results show existence of an anticyclonic gyre near the entrance of Saginaw Bay in summer, impacting water exchange between the lake and the bay. The size of this gyre varied between years, indicating potential importance of this phenomenon for inter-annual variability of chemical and biological processes in Saginaw Bay.

http://www.glerl.noaa.gov/res/glcfs/

3.2.2.d SAGEM2: Saginaw Bay

Over the past several decades Saginaw Bay has been impacted by many stressors including: excess nutrient and sediment loads, legacy and emerging contaminants, water level changes, invasive species, and nuisance algae. Past efforts to control the stressors have dealt with them individually, without consideration of interactions among stressors. More recently we have been developing models aimed at simulating the system's response to stressor interactions. We have modeled the combined impacts of phosphorus loadings and dreissenid filtering on the reoccurrence of *Microcystis* blooms. As part of a NOAA funded project we have been refining our previous model with the development of SAGEM2. One of the primary advances in SAGEM2 is the coupling of the existing lower food web framework with the new Great Lakes *Cladophora* Model (GLCM) developed by M. Auer and others. Another refinement has been linking SAGEM2 to a fine-scale (2 km) hydrodynamic model (EFDC) at the same resolution. Initial testing of the model has focused on the early 1990's, covering a period of intense data collection. The model will eventually be used in conjunction with a watershed model and a bioenergetics model of yellow perch and walleye to assist water quality and fishery managers in making informed management decisions for the system.

3.2.2.e IBM: Saginaw Bay

An Individual Based Model (IBM) was developed to simulate the growth and recruitment of walleye and yellow perch in Saginaw Bay. Walleye and yellow perch are economically and ecologically important species in the Great Lakes. Saginaw Bay historically supported large commercial and recreational fisheries for both walleye and yellow perch, but changes in the environment have altered abundance and growth rates for both species. Food availability, and competition between larval walleye and yellow perch for zooplankton, may be responsible for slow growth and small end of the year size in yellow perch and walleye. To determine how zooplankton availability affects yellow perch and walleye growth during the first year of life, we developed an individual-based model of walleye and yellow perch populations in Saginaw Bay. The models tracks consumption, growth, and survival on a sub-daily time step through one growing season. Fish grow via a modified bioenergetics subroutine and experience both predation and starvation mortality such that small individuals with low storage weights experience higher mortality rates. Simulations included varying zooplankton density and altering the timing of peak zooplankton abundance. Results from the model will be used to assess likely bottlenecks to growth of yellow perch and walleye and focus future research on these species within the bay.

3.2.2.f EFDC: Tittabawassee River

A two-dimensional EFDC model of the Tittabawassee River from the Dow Chemical Dam to the confluence with the Shiawassee River in Saginaw, MI, was developed to provide an understanding of the hydrodynamic forces and sediment transport pathways operating in this reach of the river. The river and floodplain of the Tittabawassee River in EFDC is represented by operator defined rectilinear cells, with each cell representing the area contained within the cell. Each cell is assigned an elevation and roughness value and the fully dynamic equations of energy and momentum are solved for each cell at each cell face. This model setup gives the model the ability to predict water surface elevations, the magnitude and direction of velocities, and the magnitude and direction of bottom shear stress at every point modeled within the river and floodplain. EFDC also can predict how portions of the river and floodplain will wet and dry during flood events. The ability to model the entire area using discrete cells instead of cross sections also gives the user the ability to see how flow rates and velocities vary across river cross sections of interest. Furthermore, the use of a rectilinear two or three-dimensional grid in EFDC eliminates the need to interpolate between cross sections, giving the user a complete picture of system hydrodynamics.

3.2.2.g Time Varying Fish Consumption Model: Lake Huron

The model includes the following four components: catch-at-age model for stock assessment (Sitar et al 1999), von-Bertalanffy growth model with time-varying parameters (He and Bence 2007), length-mass relations with time-varying parameters (He et al 2008), time-varying consumption by individuals and the population (a Bayesian approach to applying the Wisconsin Fish Bioenergetics model, He et al, manuscript in preparation). The model estimates annual consumption by lake trout taking into account changing population abundance, age composition, individual growth, body condition, and diet composition.

The model has been applied to three regions of the main basin of Lake Huron: the north, north-central, and south. It can be used for fish species or estimating overall lake wide consumption by major predators. It helps serve the needs of both fishery management and researchers concerning food-web dynamics and balance.

3.2.3 Lake Erie Basin

3.2.3.a HECWFS: Connecting Channels

The Huron to Erie Connecting Waterways Forecasting System (HECWFS) model was developed for research and management. It provides a missing link in NOAA forecasting models of the Great Lakes. It was developed in part for research of spill scenario forecasts in the St. Clair River and drinking water intakes. HECWFS is a 3D hydrodynamic model for currents and water levels in St. Clair River, Lake St. Clair, and Detroit River based on FVCOM model code. It predicts water levels within 3 cm (validated by 10 NOAA gauges), and currents in the St. Clair River within 12% uncertainty (compared to current meter at Blue Water Bridge). Limited other validations, and model is only as accurate as the meteorological and hydraulic forcing conditions measured in the Corridor.

3.2.3.b EFDC: Buffalo River

The Buffalo River model includes a hydrodynamic and water quality model of the river from its origin (confluence of Buffalo and Cayuga Creeks), through the City of Buffalo and down to Lake Erie. Portions of Cazenovia Creek and the City Ship Canal are also included in the model. The primary use of the model is to simulate the impact of combined sewer overflows on the receiving waters. The parameters of concern include fecal coliform bacteria and biochemical oxygen demand (BOD), along with the short and long term impacts of BOD on dissolved oxygen levels in the dredged portions of the Buffalo River.

3.2.3.c EFDC: Niagara River

A hydrodynamic and water quality model utilizing the Environmental Fluid Dynamics Code (EFDC) was calibrated for Niagara River for the section from the downstream end of Lake Erie to the approximate northern municipal boundary of the City of Buffalo. The calibrated hydrodynamic model extends further downstream from the Lake Erie boundary to

Niagara/American Falls. Both models also include Black Rock Canal from the Erie Basin Marina to the Black Rock Lock, and the segment of Scajaquada Creek downstream of the Grant Street dam. The Black Rock Canal portion of the Niagara River model simulates hydrodynamics and bacteria. As described in Section 5 below, a separate Black Rock Canal model was constructed to model dissolved oxygen.

Transport and jamming of river ice can interfere with hydropower production, cause excessive shoreline erosion, damage hydraulic structures, and produce severe ice jam flooding. Existing ice transport and ice jam theories do not consider the dynamics of ice motion. They can not be used to predict the time and location of the formation of ice jams. A two-dimensional numerical model DynaRICE© has been developed for simulating the dynamic transport of river ice and ice jam formation. The model was applied to the upper Niagara River to study the ice jamming process in relation to hydropower operations on the River.

3.2.3.d ECOFORE: Lake Erie

ECOFORE is an ecological forecasting model developed for use on Lake Erie. A primary goal of ECOFORE is to assess and refine the existing forecasting models which integrate various components such as hydrology, nutrient input, species health effects, and species movement patterns. Several models were analyzed, calibrated and enhanced in order to improve forecasting accuracy and also go beyond just providing scientific data. Several of these models were Soil Water and Assessment Tool (SWAT), Distributed Large Basin Runoff Model (DLBRM), a 1-D thermal water quality model, a 3-D hydrodynamic water quality model, Spatially-Explicit Growth Rate Potential model (SE-GRP), Individual Based Bioenergetics Models (IBM), and a Comprehensive Aquatic Simulation Model (CASM). In concert, these enhanced models will enable the construction of various potential scenarios for consideration in future policy decisions about managing hypoxic conditions in the lake. http://snre.umich.edu/scavia/ecofore/models/

3.2.3.e BRNS: Lake Erie

The Biogeochemical Reaction Network Simulator (BRNS) provides a simulation environment in which transport processes are interfaced with relevant biogeochemical reactions. The BRNS consists of three key elements: (1) a MAPLE pre-processor, containing an automated procedure for model code generation (2) a numerical engine, combining standard routines for solving transport equations, and sets of coupled nonlinear process equations generated by the MAPLE pre-processor; and (3) a Web-distributed Knowledge Base (KB). The Automatic Code Generator translates user-specified information (size of the problem, variables, reaction stoichiometries, kinetic expressions, boundary conditions, etc) plus information extracted from the Knowledge Base into Fortran code. In this approach, it is at the level of an easily accessible open resource, the KB, that process-based theoretical and experimental advances are incorporated in the modeling process.

The Knowledge Base currently assembles the information required to model the cycles of C, N, P, H, O, S, Fe, and Mn. The following sets of reactions are considered: organic matter oxidation pathways, secondary redox processes (chemolitotrophic and abiotic redox reactions), homogeneous acid dissociation reactions, non-redox mineral precipitation and dissolution, ion exchange on mineral surfaces. This model was utilized to estimate the Sediment Oxygen Demand (SOD) rates in the central basin of Lake Erie.

http://www.geo.uu.nl/Research/Geochemistry/RTM_web/project1.htm

3.2.3.f CE-QUAL-W2: Western Basin of Lake Erie

CE-QUAL-RIV1 is a one-dimensional (cross-sectionally averaged) hydrodynamic and water quality model, meaning that the model resolves longitudinal variations in hydraulic and quality characteristics and is applicable where lateral and vertical variations are small. CE-QUAL-RIV1 consists of two parts, hydrodynamic and water quality. Each of these parts is a separate computer code (RIV1H, the Hydrodynamic code and RIV1Q, the water Quality code). The hydrodynamic code is applied first to predict water transport and its results are written to a file which is then read by the quality model. It can be used to predict one-dimensional hydraulic and water quality variations in streams and rivers with highly unsteady flows, although it can also be used for prediction under steady flow conditions.

RIV1H predicts flows, depths, velocities, water surface elevations and other hydraulic characteristics. The hydrodynamic model solves the St. Venant equations as the governing flow equations using the widely accepted four-point implicit finite difference numerical scheme.

RIV1Q can predict variations in each of twelve state variables: temperature, carbonaceous biochemical oxygen demand (CBOD), organic nitrogen, ammonia nitrogen, nitrate + nitrite nitrogen, dissolved oxygen, organic phosphorus, dissolved phosphates, algae, dissolved iron, dissolved manganese, and coliform bacteria. In addition, the impacts of macrophytes can be simulated. Numerical accuracy for the advection of sharp gradients is preserved in the water quality code through the use of the explicit two-point, fourth-order accurate, Holly-Preissman scheme.

This model was applied to the western portion of Lake Erie to determine the basin wide effects that the invasive zebra mussels are having on the reduction of algae near shore.

http://www.wes.army.mil/el/elmodels/w2info.html
http://civil.queensu.ca/people/faculty/boegman/publications/documents/boegman_etal_LO_2008.pdf

3.2.3.g ELCOM-CAEDYM: Lake Erie

A study was done to perform a simulation of the dissolved oxygen (DO) dynamics in the central basin of Lake Erie using a three-dimensional hydrodynamic model (ELCOM) coupled with an aquatic ecological model (CAEDYM). The objective was to simulate the recurrent hypoxic conditions that occur in the shallow hypolimnion of the central basin of the lake after the onset of stratification. In early spring, oxygen concentrations are relatively high, but by late summer, large areas in the central basin of Lake Erie are effectively hypoxic (<2 mg). This numerical modeling study successfully reproduced horizontal variability and vertical decay of dissolved oxygen during 1994. The magnitude of oxygen depletion has been observed to vary inter-annually depending on water temperature and the thickness of the hypolimnion, which will be investigated further with ELCOM-CAEDYM simulations for other years.
http://www.iemss.org/iemss2006/papers/s2/45_Leon_1.pdf

3.2.3.h EFDC: Maumee Bay and Maumee River

The overall focus of the model is to quantify the relationship between loading of solids and nutrients to the model domain, hydrometeorological forcing conditions, hydrologic flows and circulation, and dredging operations to sediment deposition in the navigation channel, hazardous algal blooms of *Microcystis* in the lower Maumee River and its western basin plume, and nearshore nuisance algal growth and associated fouling of shorelines. The model facilitates an estimation of the relative contribution of Maumee watershed loads, loads of sediment and nutrients from other sources to the lower Maumee River and to the western basin of Lake Erie, dredging operations in the Maumee River navigation channel, and hydrometeorological conditions in the system (e.g., resuspension events in the western basin of Lake Erie).

A suite of public domain modeling tools were selected to form the overall framework for the Lower Maumee River / Maumee Bay (LMR-MB) model. The *Environmental Fluid Dynamics Code* (EFDC) model was selected to serve as both the hydrodynamic sub-model and the sediment transport sub-model. EFDC is an open source, public-domain model code developed and supported by the U.S. EPA. The *Row-Column AESOP* (RCA) model, which was originally developed by HydroQual, Inc., has been significantly modified by LimnoTech to serve as the water quality sub-model, and *Simulating Waves Nearshore* (SWAN) was selected as the wind-wave sub-model. The selection of these sub-models and configuration of the model framework to the LMR-MB system are described in detail in Chapter 3. The linked hydrodynamic – sediment transport – water quality model was configured to represent the Lower Maumee River / Maumee Bay system for the 2004-05 period based on available data obtained from a variety of sources, including the USACE, U.S. Geological Survey (USGS), Heidelberg University, the University of Toledo, National Oceanic and Atmospheric Administration (NOAA), and other sources.

3.2.3.i A2EM: Sandusky Bay

A three Dimensional Advanced Aquatic Ecosystem Model (A2EM-3D) was applied to the waters of Sandusky Bay and portions of western Lake Erie. The A2EM framework consists of a linked hydrodynamic and water quality model capable of simulating complex interactions among physical, chemical, and biological processes within the water column and sediment of a river, embayment, or lake.

The hydrodynamic model consists of the Environmental Fluid Dynamics Code (EFDC), which is a public domain open source model maintained by the United States Environmental Protection Agency's (USEPA) Ecosystem Research Division (Tetra Tech, 2007)

The water quality model consists of a modified version of the open source and publicly available version of the Row Column AESOP model (RCA) maintained by Hydroqual (Hydroqual, 2004). The model includes a full nutrient sub model to simulate interactions among major nutrients (carbon, nitrogen, phosphorus, and silica), dissolved oxygen, and inorganic suspended solids.

3.2.3.j Cladophora Growth Model: Nearshore Lake Erie

This model is based on the "Canale and Auer" model developed by R.P. Canale, M.T. Auer, L. Graham, and colleagues during the late 1970s and presented as six papers in a special issue of the Journal of Great Lake Research focused on the ecology of filamentous algae (JGLR 8(1), 1982).

Conceptually, the growth model is based on several dynamic variables including: light, temperature, phosphorus, and carrying capacity (Fig. 2). The standing crop, or biomass, is a function of growth and loss (respiration and sloughing) terms. The model predicts specific growth by subjecting an empirically determined maximum specific growth rate, based on available light and temperature, to forcing functions that account for *in situ* conditions that are, most often, sub-optimal. The "Canale and Auer" model was validated and slightly modified to simulate Cladophora growth and biomass accrual in eastern Lake Erie.

3.2.3.k NWRI 9 box model: Lake Erie

This phosphorus-oxygen model for Lake Erie is based on the nine boxes consisting of the three basins, each of which has three vertical thermal layers, using a daily time step. The vertical layer thicknesses change according to the time variation of the thermocline structure as predicted by a 1-D thermocline model. Advection processes across the boxes and layers are based on observed data and 3-D lake hydrodynamic model results. It considers phosphorus loading, plankton uptake and respiration, physical and chemical phosphorus regeneration from sediment, and sediment oxygen demand, etc. It was calibrated with 1978 data, verified with those for 1967-1977 and post-audited for 1979-1982. Relationships between phosphorus loading and dissolved oxygen concentration for Central Basin Hypolimnion were derived for different thermal stratification conditions. Also, analysis of the anoxia conditions in Lake Erie Central Basin was carried out to compare effects of pre- and post-zebra mussel periods using data of 1978, 1984, 1994 and 1997. The model has been applied to Lake Erie to simulate phosphorus and dissolved oxygen processes for research and management problems related to anoxia.

3.2.4 Lake Ontario Basin

3.2.4.a WASP: Don River

The Don River and in particular the lower reach is severely polluted. A modular modeling package, WASP4, was applied to the Lower Don River to investigate processes controlling the hydrodynamics and water-quality of the river. These models were used to evaluate the hydrologic dynamics and the transport by and transformation of contaminants in the river to provide water quality management alternatives that are environmentally and ecologically sound and economically feasible.

The WASP4 modeling package is based on a mass balance of various solutes in the water body, and contains independent blocks for hydrodynamic, eutrophication, and toxicant contamination simulation. These blocks interact through input/output files created automatically or by users. The latter allows us to use the other programs interactively to simulate additional processes.

http://iahs.info/redbooks/a219/iahs_219_0251.pdf

3.2.4.b ELCOM-CAEDYM: Lake Ontario

A Study was performed on Lake Ontario at the University of Waterloo to gain an understanding of Cladophora growth, detachment, and transport in the Pickering area. A goal was to identify major areas where growth was occurring and determine the effect that the Cladophora is having on the Pickering nuclear powerplant. They also wanted to determine the effect of the Pickering thermal plume and the Duffin Creek Water Pollution Control Plant nutrient loading on Cladophora growth. The study coupled the ELCOM 3D hydrodynamic model along with the CAEDYM aquatic ecosystem model to accomplish this goal.

http://www.opg.com/community/activities/pickering/PCAC%20MinutesAppendix/10.05.18%20PCAC%20Minutes%20Appendix%202.pdf

3.2.4.c LOTOX2: Lake Ontario

A mass balance and food chain bioaccumulation model, LOTOX2, has been developed to address the needs of the Lake Ontario LaMP and TMDL formulation. LOTOX2 has been calibrated for total PCBs in the lake using long-term data and reconstructed loading history to conduct a long-term hindcast of Cesium-137 and total PCBs in water, bottom sediments, and adult lake trout. First, new data collected in the Lake Ontario system in the prior four years were compared with the existing model simulation. Since LOTOX2 was initially calibrated through 1995, this process provided an opportunity to confirm the capability of LOTOX2 to forecast the time trends of PCB concentrations in the various lake media. Second, LOTOX2 was linked to a hydrodynamic model of Lake Ontario to develop a better representation of currents and circulation in describing the spatial distribution of PCBs in the lake, and to determine if that increased hydrodynamic resolution would have an impact on lake-wide average concentrations (it was determined that such resolution resulted in only minor changes in lake-wide concentrations). Third, researchers investigated an inconsistency between the outflow PCB mass load measured in the south channel at Wolfe Island, and the model-computed PCB outflow. Finally, several load category management scenarios were run to demonstrate the potential value of the model for making a TMDL determination.

3.2.4.d FGETS: Lake Ontario

FGETS (Food and Gill Exchange of Toxic Substances) is a FORTRAN simulation program that predicts temporal dynamics of a fish's whole body concentration (g chemical / (grams live weight fish)) of non-ionic, non-metabolized, organic chemicals that are bioaccumulated from water and food. The model is based on a set of diffusion and forced convection partial differential equations, coupled to a process-based fish growth formulation. A full description of the theoretical bases and development of these equations is presented in Barber et al. (1991). FGETS also calculates the time to reach a lethal activity in the fish assuming that the chemical has a narcotic mode of action. In this scenario, FGETS was utilized to model the PCB dynamics in Lake Ontario Salmonids.
http://eng.odu.edu/cee/resources/model/mbin/fgets/dos/fgets_manual.pdf

http://www.epa.gov/ceampubl/fchain/bass/index.html

3.2.4.e Food Web Mass Balance: Lake Ontario

A mass balance study was performed on Alewives in Lake Ontario. Alewives *Alosa pseudoharengus* are the dominant prey fish in Lake Ontario, and their response to ecological change can alter the structure and function of the Lake Ontario food web. Using stochastic population-based bioenergetic models of Lake Ontario alewives for 1987–1991 and 2001–2005, the changes to alewife production, consumption, and associated bioenergetic ratios were evaluated after invasive-induced food web disruption.

A key component of the blueprint is a Federated Architrecture, the concept of distributed data, services and products with information flowing both ways between the participating components; this may be regional and inter-agency.

The DMAC subsystem is defined by managing these data classes:

- Regular grid (some models, satellite level 3)
- Point time-series
- Profile time-series
- Collection of points or profiles
- Trajectory (2d and 3d)
- Collection of trajectories
- Unstructured grids
- Curvilinear grids
- Swath (Satellite Level 2)
- Polygon

The DMAC subsystem is defined by:

DMAC DATA SERVICES

- Data Access Services
- Data Subscription and Alert Services

DMAC UTILITY SERVICES

- Service Registry
- Data Catlog Service
- Mapping and Visualization Service
- Format Conversion Service
- Coordinate Transformation Services
- Product Generation Services
- Data Integration Services
- Workflows

DMAC COMPONENTS

- System Viewer
- System Monitor

DMAC STANDARDS

- Metadata Standards
- QA/QC Standards
- IT Security Standards
- Controlled Vocabulary

4.3 NOAA GTS

The Global Telecommunication System (GTS) has been established as the communications network for data exchange for the World Meteorological Organization (WMO), a specialized agency of the United Nations (UN). The WMO programs are supported in part through the World Weather Watch. World Weather Watch combines information from locally maintained observing systems, telecommunication facilities, and data processing and forecasting centers to makes available meteorological and related environmental information globally. The exchange of data and products is accomplished through the warning centers and watch providers; the providers share data and information with other warning centers.

The network utilizes standardized data formats and content from weather stations, satellites, and numerical weather prediction centers.

http://afsjournals.org/doi/abs/10.1577/M10-023.1

3.2.4.f Wetland Plant Community Predictive Model: Lake Ontario Shoreline

Integrated, GIS-based, wetland predictive models were constructed to assist in predicting the responses of wetland plant communities to proposed new water-level regulation plans for Lake Ontario. The modeling exercise consisted of four major components: 1) building individual site wetland geometric models; 2) constructing generalized wetland geometric models representing specific types of wetlands (rectangle model for drowned river mouth wetlands, half ring model for open embayment wetlands, half ellipse model for protected embayment wetlands, and ellipse model for barrier beach wetlands); 3) assigning wetland plant profiles to the generalized wetland geometric models that identify associations between past flooding / dewatering events and the regulated water-level changes of a proposed water-level-regulation plan; and 4) predicting relevant proportions of wetland plant communities and the time durations during which they would be affected under proposed regulation plans. Based on this conceptual foundation, the predictive models were constructed using bathymetric and topographic wetland models and technical procedures operating on the platform of ArcGIS.

3.2.5 Anthropogenic Stressor Model: Lake Superior Watersheds

The Lake Superior Anthropogenic Stressor Model is a spatial database of high-resolution scalable watersheds containing attributes related to anthropogenic stress (e.g. # point sources, land use, population and road density). The watershed stressor summaries are based on a high-resolution watershed classification derived using ArcHydro - the Lake Superior basin comprises 130,921 subwatersheds, with 6,993 aggregated watersheds that flow to the coast. The stressor gradient for the Lake Superior basin will be completed by Dec 2009. We are currently pursuing and have received interest in extending this work to the remaining Great Lakes.
http://www.nrri.umn.edu/lsgis2

4. REFERENCES

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APPENDIX A
GREAT LAKES MODEL INVENTORY

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Appendix A - List of Models Included in the Model Inventory

No	Model ID	ModelName
1	A2EM	Advanced Aquatic Ecosystem Model
2	ALIS	Aquatic Landscape Inventory System
3	ANN	Saginaw Bay Artificial Neural Network
4	AnnAGNPS	Annualized Agricultural Non-Point Source Pollutant Loading Model
5	AQUATOX	A Simulation Model for Aquatic Ecosystems
6	ATLSS	Across Trophic Level System Simulation
7	BASINS	Better Assessment Science Integrating point and Nonpoint Sources
8	BRNS	Biogeochemical Reaction Network Simulator
9	CE-QUAL-ICM	Integrated-Compartment Eutrophication Model
10	CE-QUAL-RIV1	One-dimensional, dynamic flow and water quality model for streams
11	CE-QUAL-W2	A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model
12	CGM	Cladophora Growth Model
13	CH3D-SED	Curvilinear Hydrodynamics in Three-Dimensions
14	CHARM	Coupled Hydrosphere-Atmosphere Research Model
15	DL	Digital Watershed
16	DLFM	Dynamic Linear Forecasting Models
17	DW&L	Digital Watershed & L-THIA
18	DynaRICE	Dynamics of River Ice
19	ECOFATE	Ecological Fate and Transport
20	EFDC	Environmental Fluid Dynamics Computer Code
21	ELCOM-CAEDYM	ELCOM & Computational Aquatic Ecosystem Dynamics Model
22	ELM	Everglades Landscape Model
23	EUTROMOD	Watershed and Lake Modeling Procedure
24	EXAMS	Exposure Analysis Modeling System
25	FGETS	Food and Gill Exchange of Toxic Substances
26	GBTOX	Green Bay Toxics Model
27	GLCFS	Great Lakes Coastal Forecasting System
28	GLMOD	Great Lakes Multi-Media Screening Model
29	GMS	Groundwater Modeling System
30	HEC-RAS	Hydrologic Engineering Centers River Analysis System
31	HECWFS	Huron-Erie Connecting Waterways Forecasting System
32	HEP/HSI	Habitat Evaluation Procedures/Habitat Suitability Indices
33	HES	Habitat Evaluation System
34	HIT	High Impact Targeting
35	HSPF	Hydrological Simulation Program – FORTRAN
36	IERM	Integrated Ecological Response Model
37	IFIM	The Instream Flow Incremental Methodology
38	INCA-C	Integrated Catchments Model for Carbon
39	LBRM	Large Basin Runoff Model
40	LOFWMB	Lake Ontario Comparative Offshore Food Web Mass Balance
41	LOTOX2	Lake Ontario Toxics Model 2
42	LS-ASM	Lake Superior Anthropogenic Stressor Model
43	MIKE 21	Generalized Modeling Package 2-D-Hydrodynamics
44	MODFLOW	Modular Three-Dimensional Ground-Water Flow Model
45	NWRI WQ	NWRI 9-Box Water Quality Model for Lake Erie
46	OFAT	Ontario Flow Assessment Techniques
47	POM	Princeton Ocean Model
48	PVA	Population Viability Analysis
49	QUAL2E	The Enhanced Stream Water Quality Model
50	QUAL2K	River and Stream Water Quality Model
51	RATECON	Rate Constant Model for Chemical Dynamics
52	RICEN	Numeric River Ice Model
53	RMA2	Resource Management Associates 2 Model
54	RMA-2V	2-Dimensional Vertically averaged hydrodynamic model
55	SAGEM	Saginaw Bay Ecosystem Model

No	Model ID	ModelName
56	SALMOD	Salmonid Population Model
57	SMPTOX4	Simplified Method Program - Variable-Complexity Stream Toxics model
58	SPARROW	Spatially Referenced Regression nn Watershed Attributes
59	SSOAP	Sanitary Sewer Overflow Analysis and Planning Toolbox
60	STEMP	Stream Network/Stream Segment Temperature Models
61	SWAT	Soil and Water Assessment Tool
62	TVFCM	Time Varying Fish Consumption Model
63	WAM	Watershed Assessment Model
64	WARMF	Watershed Analysis Risk Management Framework
65	WASP	Water Quality Analysis Simulation Program
66	WetlandResponse	Wetland Response to Lake Level Declines
67	WetlandResponse2	Wetland Plant Community Predictive Model (GIS based)

TECHNICAL MEMORANDUM 6: CATALOGUE OF USER NEEDS

Near-Term Design of the Great Lakes Observing System Enterprise Architecture

June 30, 2011

Prepared for:
NOAA-GLERL
Contract Number:
WC133R-10-CN-0350

By:
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The NOAA National Weather Service (NWS) directly supports operational activities through the exchange of data on a worldwide basis. The NWS offers three protocols for delivering information to the GTS. All of these communication links are operated as either point-to-point or broadcast. A large number of International centers are implementing data exchanges using the Internet as an additional connectivity or as backup. The World Wide Web (Internet) connections provide exchange of files and messages over TCP/IP, the basic Internet communications protocol. This is enhancing the ability to exchange data and products among the members of the WMO by using standard commercially available software and protocols such as FTP, E-Mail, and HTTP.

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TABLE OF CONTENTS

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory (NOAA-GLERL) was funded in 2010 under the Great Lakes Restoration Initiative (GLRI) to develop a near term design for the Great Lakes Observing System Enterprise Architecture. This memo is the sixth technical memo in a series of six that summarizes the current observation systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six technical memos cover the following topics:

1. Current state of IOOS observing systems
2. Cost associated with observing systems
3. Inventory of Great Lakes observing systems and monitoring programs
4. Summary of Great Lakes DMAC infrastructure
5. Great Lakes models, scale, and operational status
6. Catalogue of Great Lakes user needs

Each of these technical memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

This Tech Memo documents a comprehensive list of users and user requirements, based on the requirements identified in the October 2010 Project Plan and previous work done by the Great Lakes Observing System Regional Association (GLOS) to catalogue the full set of user needs. The enterprise system components are being tabulated and evaluated by the group according to the identified system and user requirements. Identified user needs will serve as the primary means by which the full list of alternatives will be shortened and focused. The project team worked with GLOS and other Great Lakes resources to identify and prioritize a list of users and end user requirements, drawing on the collective knowledge of the Great Lakes interests represented by the project team and the project partners.

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2. PRIORITIES AND OBJECTIVES

The Great Lakes Observing System Enterprise Architecture project is intended to leverage and build on the foundation of three similar and complimentary initiatives and programs. The project team is working and collaborating with agency partners representing the governing structure of the GLRI, the Integrated Ocean Observing System (IOOS), and the GLOS for GLERL. The project is funded by the GLRI and is intended to produce an observing system design that will provide data on the physical, chemical, and biological parameters necessary for effective management of near-shore aquatic resources to support remediation, restoration, and conservation actions through the GLRI. The observing system is intended to gather data to help address the goals laid out by IOOS, GLOS, and the GLRI.

IOOS is an integrated system of observing systems (the RA's) that routinely and continuously provides quality controlled data and information on current and future states of the oceans and Great Lakes from the global scale of ocean basins to local scales of coastal ecosystems. It is designed to provide data in forms and at rates required by decision makers to address seven societal goals:

1. Improve predictions of climate change and weather and their effects on coastal communities and the nation;
2. Improve the safety and efficiency of maritime operations;
3. Mitigate the effects of natural hazards more effectively;
4. Improve national and homeland security;
5. Reduce public health risks;
6. Protect and restore healthy coastal ecosystems more effectively; and
7. Enable the sustained use of ocean and coastal resources.

GLOS has developed a conceptual plan for its regional coastal ocean observing system (RCOOS) that addresses how each of the IOOS societal needs will be met in the Great Lakes through its RCOOS (GLOS, 2007a). The Enterprise Architecture is being developed developed to meet the data and forecasting needs that GLOS has identified.

1. Improve early identification of climate change impacts on the thermal structure and chemistry of the Great Lakes
2. Reduce risks of contaminated water supplies and improve predictive capabilities to protect public use of bathing beaches
3. Enhance understanding of nutrient dynamics, algal blooms, and other factors adversely affecting a viable fishery

4. Reduce loss of life and property damage to commercial navigation and recreational boating, while increasing economic efficiencies of commercial navigation operations.

The GLRI operates under the Great Lakes Multi-Year Restoration Plan (EPA, 2010). This plan identifies goals, objectives, targets and projects to address the Great Lakes most significant environmental issues within the Great Lakes ecosystem. Being funded through the GLRI, this project will satisfy many of the activities described in the multi-year action plan outline and address the following GLRI goals.

1. *Toxic Substances and Areas of Concern: Measuring Progress and Assessing New Toxic Threats* - Measure progress in cleaning up toxics in the Great Lakes environment through comprehensive monitoring and assessment. Identify significant sources and impacts of new toxics to the Great Lakes ecosystem through robust surveillance as well as laboratory and field studies, in order to devise and implement effective control strategies.
2. *Invasive Species: Establish early Detection and Rapid Response Capability* - Work with federal and state jurisdictions to initiate surveillance activities to detect new invaders and establish the capacity, methods, and contingency plans for a rapid response. Joint planning will allow the mobilization of shared resources to create the best opportunity for eradication.
3. *Nearshore Health and Non-Point Source pollution: Generate critical information for protecting nearshore health* - The nearshore environment of the Great Lakes is highly varied, including relatively unspoiled shorelines, highly urbanized reaches, tributary mouths, embayments, wetlands and other environmental features. These activities will promote the collection of data about nearshore conditions and stresses, the assessment of information and management implications, or the dissemination of information to all potential users in the Great Lakes community.
4. *Habitat and Wildlife Protection: Identify, inventory, and track progress on Great Lakes Habitats, including coastal wetlands restoration* - Assess progress toward restoring Great Lakes habitats by establishing baseline conditions and tracking trends; highlight the importance of coastal wetland conservation and restoration by implementing a long-term coastal wetland monitoring program and enhancing the National Wetlands Inventory.
5. *Accountability, Monitoring, Evaluation, Communication, and Partnerships*: *Measure and Evaluate the health of the Great Lakes Ecosystem using the best available Science* - Enhance existing programs that measure and assess the physical, biological, and chemical integrity of the Great Lakes, including the Connecting Channels. Implement strategic components relevant for Great Lakes decision-making of the U.S. contribution to the Integrated Earth Observation System and the Integrated Ocean Observing System as part of the Global Earth Observing System of Systems. Promote the development and implementation of science-based indicators that will better assess and provide a better measure of accountability of actions to improve the health of the Great Lakes ecosystem.

3. USER COMMUNITIES

The list of Great Lakes Users considered in this document encompasses a broad spectrum of stakeholders involved in science and research, recreation, commerce, power supply, public and environmental health and safety, navigation, coastal development and wildlife and habitat preservation. The User Categories representing these stakeholder interests are summarized in Table 1 and include:

- Fisheries
- Water Quality Managers
- Climate Change Research and Planning
- Public Health (Drinking Water)
- Maritime Operations (shipping and navigation)
- Power Generation
- Beaches
- Recreational Boaters
- Emergency and Spill Response

Table 1 also includes management issues identified for each user group and the associated data needs. The appropriate goals addressed by each user need are also included.

3.1 FISHERIES

The Fisheries user community consists of fisheries managers and fisherman, who may have different needs for information. The fisherman want to know where they can catch the fish they want and they make use of the Sea Grant Coast Watch System which provides near real-time satellite info on surface temps as a guide to where the fish are. They also need to have information on wind, waves, and weather in order to know if there are dangerous conditions on the lake that would prevent fishing.

The fisheries managers are interested in rehabilitation and conservation of healthy aquatic ecosystems in the Great Lakes that support fisheries with increasing contributions of naturally reproducing fish. They are also dedicated to conservation of biological diversity through rehabilitation of fish populations, species, communities and their habitats. Invasive species, ecosystem changes and declining fisheries are all issues for fisheries managers.

3.2 WATER QUALITY MANAGERS

Water quality managers in the Great Lakes are required to deal with numerous issues affecting water quality. Forty-three Areas of Concern (AOCs) have been identified in the Great Lakes Basin: 26 are located entirely within the United States; 12 located wholly within Canada; and five are shared by both countries. Two Canadian AOCs have been delisted and one U.S. AOC has been delisted, leaving 30 AOCs remaining on the U.S. side of the border.

Remedial Action Plans have been developed for each of these AOCs to address impairments to any one of 14 beneficial uses associated with these areas. Beneficial Use Impairments (BUIs) reflect chemical and biological impacts (i.e., loss of wildlife and habitats) on Great Lakes waters and harbors. BUIs are driven by contaminated sediments, which have been identified as serious problems in many AOCs. Once all BUIs are addressed, the AOC can be delisted (a lengthy process in large watersheds).

Beneficial Use Impairments (BUIs):

- Restrictions on fish and wildlife consumption
- Tainting of fish and wildlife flavor
- Degradation of fish and wildlife populations
- Fish tumors or other deformities
- Bird or animal deformities or reproduction problems
- Degradation of benthos
- Restriction on dredging activities
- Eutrophication or undesirable algae
- Restrictions on drinking water consumption, or taste and odor
- Beach closings
- Degradation of aesthetics
- Added costs to agriculture and industry
- Degradation of phytoplankton and zooplankton populations
- Loss of fish and wildlife habitat

3.3 PUBLIC HEALTH (DRINKING WATER AND WASTEWATER TREATMENT)

Over 90% of the 29 million US residents of the Great Lakes basin get drinking water from the Great Lakes. Drinking water utilities need accurate predictions of factors impacting water quality (contaminants, water chemistry, algal blooms, temp) at the intake, which can be used to maximize the efficiency of the treatment process. The WWTP operators benefit from accurate predictions of the magnitude and timing of flow events as well as from predictions of how development (increasing impervious surfaces) and climate change may alter flow regimes (especially max flow rate).

3.4 MARITIME OPERATIONS

The Great Lakes are home to more than 15 major Canadian and US ports, over half with a depth of more than 27 feet, and hundreds of smaller harbors. Issues affecting commercial navigation include the impacts of ice cover on the length of the shipping season, weather related safety, the impact of water levels and bathymetry impacts on cargo loads. High water velocity and cross currents can be hazardous to ship transit in inter-connecting channels. Shippers are also interested in invasive species. In addition, harbor-specific models of circulation dynamics would be useful tools in predicting the efficacy of any proposed rapid response.

3.5 POWER GENERATION

Water levels in the Great Lakes have a major impact on hydropower generation. The amount of hydropower generated depends on the amount of water available and the difference in water levels upstream and downstream of the plant (head). In addition, invasive species such as zebra mussels can foul water intake pipes at fossil fuel plants. These facilities would benefit from the prediction of rate at which zebra mussels will accumulate, which allows the company to set cleaning schedules that maximize usefulness while minimizing cleaning costs.

3.6 BEACHES

Beaches and recreational waters provide enjoyment for humans and habitat for local wildlife. The 2004 Clean Beaches Plan outlined two major goals for completion within two years: promote recreational water quality programs nationwide and create scientific improvements that support timely recreational water monitoring and reporting (EPA). Impaired beaches and recreational water quality can seriously degrade quality of life and the economy of the Great Lakes basin. Understanding the nature, extent and causes of problems, as well as finding solutions, is an important challenge that must be met by all those who care about the Great Lakes (IJC, Aug-09). Reliable information, including ecological and source tracking methods, water quality data, levels of use, and use impairment, are essential for determining the health of a lake and for developing a management plan to protect the lake (IJC, Aug-09; MILP/MNSP).

Along the thousands of miles of Great Lakes shoreline are 822 monitored beaches, but not all places where people swim are monitored, and others are monitored only sporadically.

3.7 RECREATIONAL BOATERS

One third of all registered boaters in the US reside in the Great Lakes basin, where boating supports close to 250,000 jobs. Boaters need information on wind, waves, and weather in order to know if there are dangerous conditions on the lake to protect boater safety. Water levels cause docks and ramps to be inaccessible, accessibility to lakes and rivers can be reduced, which can shorten the boating season.

3.8 EMERGENCY AND SPILL RESPONSE

Each year in the eight Great Lakes states each year there are approximately 5,000 incidents in which recreational boaters have needed and gotten response assistance from the Coast Guard, often leading to lives being saved. According to Ninth Coast Guard District, approximately 80 percent of these incidents involve disabled or distressed boats. The Great Lakes Operational Forecast System environmental data is critical in shaping decisions on where to focus search and rescue efforts. Real time information on wind, waves, currents, and weather are essential. This also applies to clean up efforts from spills of hazardous substances in the Great Lakes.

5. NOAA NATIONAL DATA BUOY CENTER (NDBC)

The National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) is part of the National Weather Service (NWS) and is headquarted in Stennis, MS. NDBC designs, develops, operates, and maintains a network of data collecting buoys and coastal stations. NDBC manages atmospheric and oceanographic variables measured from monitoring systems. Moored buoys and C-MAN stations are transmitted hourly through NOAA Geostationary Operational Environmental Satellites (GOES) to a ground receiving facility at Wallops Island, VA, operated by the NOAA National Environmental Satellite, Data, and Information Service (NESDIS). Some stations report via commercial low earth orbiting satellites. The satellite reports are immediately relayed to the NWS Telecommunications Gateway (NWSTG) in Silver Spring, MD.

NDBC also serves as a data assembly center for receiving, quality controlling, and disseminating measurement data from other stations owned and maintained by non-federal regional ocean observing systems, including the IOOS regional associations (RAs).

NDBC play a key role in the IOOS community as a central data warehouse of in-situ physical oceanographic parameters. The vast majority of in-situ physical parameters collected by the IOOS regions is delivered to NDBC where it is centralized with data collected from other federal programs, (e.g National Estuarine Research Reserve System - NERRS).

The connection to NDBC is quite simple, NDBC define an XML-based data transfer file that is created by the regional data providers. NDBC then gather this data routinely and integrate the data into a centralized Oracle database. A few of the larger data providers to NDBC use an older methodology; a “modem kit” provided by NDBC that facilitates delivery of data to the center; the majority of regional providers use the XML-based file approach.

NDBC make the data available in a variety of formats/services from the data store including SOS, KML, ASCII, and NetCDF. A new initiative is underway at NDBC to store observation data as NetCDF4 and make available through a THREDDS server.

One of the key advantages for data providers in IOOS is that data provided to NDBC is then delivered to the GTS system, one of the upcoming requirements for the IOOS regional data providers.

NDBC do not generally manage chemical and biological parameters, but could expand their system to do that. They also do not generally manage gridded data, although they do handle gridded model that is used for data comparison analysis, although not in real-time.

3.9 COASTAL MANAGEMENT ISSUES

Coastal management means achieving a balance between natural resources preservation and economic development along the Great Lakes coasts. The Great Lakes shoreline is equal to almost 44 percent of the circumference of the earth or 10,000 miles.

Coastline management in the Great Lakes includes reducing erosion and coastal hazards, preserving maritime and cultural heritage, supporting coastal dependent uses, creating and enhancing public access, balancing coastal community development and protecting and restoring coastal habitat, including wetlands. While each state defines its coastal zone differently, the "coastal zone" of the eight Great Lakes states is more than 14,000 square miles, larger than the surface area of Lake Erie.

Property owners along the shoreline have a significant investment in shoreline property and a significant interest in maintaining the value of their property. The want to minimize negative property impacts such as, storm damage, rates of erosion and stability, flooding, degradation and loss of access.

Shoreline areas also have ecological values and functions. Great Lakes fisheries are dependent on wetlands for spawning, nurseries, and food sources. They provide essential breeding, nesting, feeding and predator evasion habitats for fish and wildlife. Natural water filtering, erosion control and sediment capture capabilities of wetlands contribute to the overall improvement of water quality.

4. USER DATA NEEDS

The information required by the user communities discussed above is listed in Table 2. The biological, chemical and physical data needed by each user is included.

The observing system will consist of a wide variety of systems and elements whose basic role is to measure fundamental parameters and variables. From the evaluation of the user community and the user needs a list of core variables was developed and is included in Table 3. The core variables will form the basis of Great Lakes data and information that is made available through GLOS; however, they will not be the only parameters that can or will necessarily be measured in the observing system.

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5. REFERENCES

Clean Beaches Coalition (CBC) – Blue Wave Campaign http://www.cleanbeaches.com

International Joint Commission (IJC) - Work Group Report on Beaches and Recreational Water Quality, Great Lakes Water Quality Agreement Priorities 2007–09 Series (August 2009) http://www.ijc.org/en/priorities/2009/beach-quality

Michigan Inland Lakes Partnership/Michigan Natural Shoreline Partnership (MILP/MNSP) – http://michiganlakes.msue.msu.edu/Home.aspx

http://michiganlakes.msue.msu.edu/MichiganNaturalShorelinePartnership.aspx

US Environmental Protection Agency (EPA) - 2000 Beaches Environmental Assessment and Coastal Health Act; 2004 Clean Beaches Plan; 2005 NEEAR Water Study/EMPACT Beaches Project.
http://water.epa.gov/type/oceb/beaches/plan.cfm
http://www.epa.gov/nheerl/neear

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TABLES

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Table 1. Catalogue of User Needs

User	Goals Addressed	Management Issue	Data Information Needs	Most Relevant Design Scale	GLOSEA Design Focus*			
					Basin Wide	Whole Lake - Lake Michigan	Regional 1 - Maumee Bay	Regional 2 - Lake Ontario Nearshore
Commercial Shipping and Maritime Operations	Improve safety and efficiency of maritime operations	Maximize shipping season	Lake ice distribution	Basin wide	X			
		Manage size of cargo/load	Coastal bathymetry, water levels	Local				
		Safety	Weather/wave forecasting, other met/weather data	Basin wide	X			
		Long term planning	Great Lakes water level forecasts	Basin wide	X			
		Environmental compliance	Ballast discharge	Basin wide	X			
			Ballast treatment	Basin wide	X			
		Search and rescue	Currents (3-D), weather	Whole lake	X			
		Oil spill	Location, amount, trajectory	Whole lake	X			
Fisheries	a) Protect and restore healthy ecosystems b) Protect and restore habitat c) Improve nearshore health	Environmental Assessment	Water temperature, water quality and lower food web productivity, sedimentation	Basin wide	X		X	
		Fish Stock	Population sizes, health, distributions, viruses, fish kills	Whole lake				
		Loss of habitat	Sedimentation/solids/land cover, bottom type characterization	Local	X		X	
		Climate Change	Meterological/Physical	Basin wide	X			
		Fish Advisories	Fish contaminants	Whole lake		X		
		Safety	Weather/wave forecasting, other met/weather data	Basin wide	X			
Water Quality Managers	a) Protect and restore healthy ecosystems b) Protect and restore habitat c) Improve nearshore health d) Clean up toxics	Eutrophication	Nutrient concentrations, lower food web productivity	Whole lake	X	X		
		HABs	Phytoplankton species/abundance, microcystis, cyanobacteria, location	Local			X	X
		Nuisance benthic algae	Cladaphora, Dreissenids, lower food web productivity, location	Local		X	X	X
		Climate Change	Meterological/Physical	Basin wide	X			
		Toxics	Contaminant concentrations, bacteria, pathogens	Whole lake		X		
		Sediment load from watershed	Suspended solids	Local			X	
		Invasive species	Biological	Whole lake		X	X	X
Drinking Water	Reduce public health risks	Water levels	Bathymetry, currents, waves, water level, temperature	Whole lake				
		Climate Change	Meterological/Physical	Basin wide	X			
		Contaminants and turbidity	Contaminant concentrations	Whole lake		X	X	
Power Generation	a) Improve homeland security b) prevent invasive species	Water levels	Bathymetry, currents, waves	Whole lake				
		Climate Change	Meterological/Physical	Basin wide	X			
		Nuisance benthic algae	Phytoplankton species/abundance & location	Local			X	
		Invasive species	Biological	Whole lake				
Recreational Boaters	Improve safety and efficiency of maritime operations	Safety	Weather/wave forecasting, other met/weather data	Whole lake	X			
		Climate Change	Meterological/Physical	Basin wide	X			
		Nuisance benthic algae	Phytoplankton species/abundance & location	Local			X	
		Water levels	Bathymetry, currents, waves	Whole lake	X			
Coastal Management	a) Protect and restore habitat b) Improve nearshore health	Shoreline erosion	Bathymetry, currents, waves	Local	X	X		
		Climate Change	Meterological/Physical	Basin wide	X			
		Invasive species	Biological	Whole lake	X			
		Loss of wetlands	Land use/land cover	Local	X	X		
Beaches	Reduce public health risks	Beach closure	Pathogens	Local	X	X		X
		Safety	Weather/wave forecasting, other met/weather data	Whole lake				
		Nuisance benthic algae	Phytoplankton species/abundance & location	Local			X	X
		Water levels	Bathymetry, currents, waves	Whole lake				
Emergency Response	Reduce public health risks	Safety	Weather/wave forecasting, other met/weather data	Whole Lake	X			
		Currents	Currents	Whole lake	X			
		Water levels	Bathymetry, currents, waves	Whole lake	X			

* These management issues and data needs are being addressed as part of the Great Lakes Observing System Enterprise.Architecture Conceptual Desigr

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TABLE 2. User Needs

USER CATEGORIES	BIOLOGICAL DATA									CHEMICAL DATA			
	Zooplankton Species	Zooplankton Abundance	Fish Species	Fish Abundance	Benthic Invertebrate Species	Benthic Invertebrate Abundance	Benthic Algae Species	Benthic Algae Abundance	Pathogen Data	Contaminants	Nutrients (water)	Dissolved Oxygen	Nutrients Sediment
Fisheries	x	x	x	x	x	x	x	x		x	x	x	x
Water Quality Managers	x	x	x	x					x	x	x	x	x
Climate Change												x	
Public Health - Drinking Water	x	x			X	X	X	X	X	x			
Maritime Operations													
Power Generation	x	x	x	x	x	x	x	x					
Beaches									x	x	x		x
Recreational Boaters													
Emergency and Spill Response												x	
Coastal Management Issues									x	x	x		x

USER CATEGORIES	PHYSICAL DATA																
	Conductivity	Water Temperature	Coastal Bathymetry	Bottom Character	Water Levels	Wave Height/ Direction	Currents (3D)	Ice Cover/ Thickness	Optical Properties	Wind Speed/ Direction	Relative Humidity	Barometric Pressure	Solar Radiation	Evaporation	Precipitation	Tributary Flow	Land Use/Land Cover
Fisheries		x	x	x	x			x	x								
Water Quality Managers	x	x		x	x	x	x	x	x	x	x	x	x	x	x		
Climate Change	x	x			x	x		x		x	x	x	x	x	x	x	x
Public Health - Drinking Water		x			x		x			x							
Maritime Operations		x	x	x	x	x	x			x			x		x		
Power Generation		x	x	x	x	x	x	x		x	x	x	x	x	x		
Beaches		x	x	x					x								
Recreational Boaters		x	x	x	x	x	x			x	x	x	x	x	x		
Emergency and Spill Response	x	x	x	x		x	x	x		x	x	x	x	x	x		
Coastal Management Issues		x	x	x	x	x	x	x	x							x	x

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TABLE 3. GLOSEA CORE VARIABLES

Program	Category	Variables	Goals Addressed		Instrument	Remote Sensing	Lab Analysis
			GLOS/IOOS Goals	GLRI Goals	P= Primary; a = auxillary		
GLOSEA	Biology	Benthic Invertebrate Abundance	E	T, HW, NS			P
GLOSEA	Biology	Benthic Invertebrate Species	E	T, HW, NS			P
GLOSEA	Biology	Benthic Algae Abundance	E	T, HW, NS	a	a	P
GLOSEA	Biology	Benthic Algae Species	E	T, HW, NS			P
IOOS	Biology	Fish Species	E	IS, T, HW			P
IOOS	Biology	Fish Abundance	E	IS, T, HW	a		P
IOOS	Biology	Zooplankton Species	E, PHR	T, HW			P
IOOS	Biology	Zooplankton Abundance	E, PHR	T, HW	a		P
IOOS	Biology	Phytoplankton Species	E, PHR	T, HW	a	a	P
IOOS	Biology	Phytoplankton Abundance	E, PHR	T, HW	a	a	P
IOOS	Biology	Pathogens	E, PHR	NS			P
GLOSEA	Chemical	Nutrients (sediment)	E	IS, HW, NS	P		
IOOS	Chemical	Contaminants	E, PHR	T, HW	a		P
IOOS	Chemical	Nutrients (water)	E	IS, T, HW, NS	a		P
IOOS	Chemical	Dissolved Oxygen	E	IS, T, HW, NS	P		a
GLOSEA	Physical	Suspended Solids	E	HW, NS	a	a	P
GLOSEA	Physical	Wind Speed and Direction	M, PHR, CW		P	a	
GLOSEA	Physical	Relative Humidity/Dew Point	CW	IS	P		
GLOSEA	Physical	Barometric Pressure	CW		P		
GLOSEA	Physical	Solar Radiation	CW		P		
GLOSEA	Physical	Evaporation	CW	IS	P		
GLOSEA	Physical	Precipitation	CW, M		P	a	
GLOSEA	Physical	River Flow	CW		P		
GLOSEA	Physical	Land Use/Land Cover	CW	NS		P	
IOOS	Physical	Conductivity	E	IS, HW, NS	P		
IOOS	Physical	Temperature	E, CW, M	IS, HW	P	a	
IOOS	Physical	Bathymetry	M	IS, HW, NS	P	a	
IOOS	Physical	Water Level	M, PHR, CW	HW, NS	P		
IOOS	Physical	Wave Characteristics	CW, M	T, HW, NS	P		
IOOS	Physical	Water Currents	M, PHR, CW	T, HW, NS	P	a	
IOOS	Physical	Ice Distribution	M, CW		a	P	
IOOS	Physical	Heat Flux	CW	HW, NS			
IOOS	Physical	Bottom Character	E	HW, NS	a		P
IOOS	Physical	Optical Properties	E	NS, HW	P	a	a

GLOS/IOOS Goals	CW	= Improve predictions of climate change and weather/mitigate natural hazards
	M	= Improve safety & efficiency of maritime ops
	PHR	= Reduce public health risks (drinking water supply/beaches), includes improving homeland security
	E	= Protect and restore healthy ecosystems/enable sustained use of ocean and coastal resources
GLRI Goals	T	= Clean up toxic substances
	IS	= Prevent and remove aquatic invasive species
	HW	= restore and protect habitat/wildlife
	NS	= Improve nearshore health and prevent NPS

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LimnoTech
Water | Environment | Scientists | Engineers

MEMORANDUM

FROM: Brian Lord

TO: Project Team

DATE: 1/20/11

PROJECT: GLOSEA

SUBJECT: GIS Database and Spatial Analysis in support of the Near-Term Design of the Great Lakes Observing System Enterprise Architecture

Introduction

This memorandum is intended to provide a brief summary of the Geographic Information System (GIS) database developed in support of the Near-Term Design of the Great Lakes Observing System Enterprise Architecture project, as well as the spatial analysis and mapping completed to date.

GIS Database

An Esri File Geodatabase (FGDB) was constructed to contain GIS datasets acquired from varying sources. The attached Table 1 lists all of the datasets in detail including the data source and the initial purpose of the dataset. The geodatabase is referenced to the following coordinate system: Great Lakes Basin, Albers projection, NAD83 Datum, Meter.

The FGDB contains:

1. Great Lake bathymetric contours of varying resolutions
2. Raster grid of water depths generated from the bathymetric contours
3. Existing real time monitoring stations (buoys, shoreline stations and water level gages)
4. Existing water quality monitoring stations
5. National Land Cover Dataset (NLCD) for the Great Lakes Basin (2001)
6. Ontario Land Cover Data Base for the Great Lakes Basin (year?)
7. Political boundaries
8. National waterway network
9. Port and waterways facilities
10. Principal ports
11. Interstates
12. Great Lakes watershed 12 digit HUC boundaries
13. Ontario watershed boundaries

Spatial Analysis

Preliminary spatial analysis has also been completed in support of the project. A brief summary of these analyses follows.

- **Real-time station buffers**. To illustrate the radius of influence of existing stations (shoreline stations and buoys only) 5 mile incremented buffers were created out to 20

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miles. This gives a preliminary look at the spatial coverage of existing stations and highlights where gaps exist.

- **Shoreline population buffers**. Points were generated at 5 mile intervals along the Great Lakes shoreline (United States only). These points were buffered at 30 mile and 60 mile increments. Census data (2007) were summarized to estimate the total population within each of these buffers. This analysis is intended to show the urban pressure that is placed on shoreline areas.
- **Watershed Land Use**. Watersheds at the HUC 8 were used as the basis for this analysis. HUCs were combined where multiple 8 Digit HUCs drained to the same discharge point/ major tributary. NLCD data from 2001 was summarized for each of the combined drainage areas. The NLCD data was generalized using the following categories: urban, agricultural, forested and wetlands. For mapping display purposes, points were placed at the outlets of each major tributary to the Great Lakes and for the direct drainage areas points were placed at each major outlet. The NLCD drainage area summary data was related to the points for mapping.

Mapping

The following maps are provided as an attachment to this document:

Existing Station Buffer Maps:

- Figure 1: 5 Mile Buffer of Buoy and CMAN Stations
- Figure 2: 10 Mile Buffer of Buoy and CMAN Stations
- Figure 3: 15 Mile Buffer of Buoy and CMAN Stations
- Figure 4: 20 Mile Buffer of Buoy and CMAN Stations

Population Summary Maps:

The following maps were designed to illustrate the urban pressure that is placed on the shoreline. Points were created at a 5 mile interval along the United States portion of the Great Lakes shoreline. These shoreline points were buffered at a 30 mile and 60 mile distance to illustrate reasonable driving distances to that particular point. The Census Bureau's 2007 Estimated Population data was used to summarize total population within each buffer polygon.

The total population value within each buffer was used to extrude the points above the ground, and classify the points on a blue to red color scale.

- Figure 5: Total Population within a 30 Mile Buffer
- Figure 6: Total Population within a 60 Mile Buffer

Land Cover Maps:

- Figure 7: 2001 NLCD data for the Great Lakes Basin – A map showing the generalized 2001 NLCD data for the Great Lakes Basin. The map also shows the outlines of the combined HUCs.

- Figure 8: Total Urban Area (acres) Within Each Drainage Area – Direct drainage outlets and major tributary outlets are extruded and classified based on the total urban land cover area. This map is intended to look at the direct drainage/nearshore implications of urban land use on water quality along the shoreline.

- Figure 9: Total Agricultural Area (acres) Within Each Drainage Area - Same as above, illustrating agriculture land cover in the drainage area.

- Figure 10: Total Forested Area (acres) Within Each Drainage Area - Same as above, illustrating forested land cover in the drainage area.

- Figure 11: Total Wetland Area (acres) Within Each Drainage Area - Same as above, illustrating wetland land cover in the drainage area.

- Figure 12: Urban Land Cover as Percentage of Total Drainage Area - Direct drainage outlets and major tributary outlets are extruded and classified based on the percentage of the total drainage area that is classified as urban.

- Figure 13: Agricultural Land Cover as Percentage of Total Drainage Area - Same as above, illustrating agriculture land cover in the drainage area.

- Figure 14: Forested Land Cover as Percentage of Total Drainage Area - Same as above, illustrating forested land cover in the drainage area.

- Figure 15: Wetland Land Cover as Percentage of Total Drainage Area - Same as above, illustrating wetland land cover in the drainage area.

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Table 1: GIS Data Summary

Feature Dataset	Feature Class	Feature Type	Purpose	Source
Bathymetry	lake_erie_bathymetry	line	Lake elevation contours	GLIN
Bathymetry	lake_huron_bathymetry	line	Lake elevation contours	GLIN
Bathymetry	lake_michigan_bathymetry	line	Lake elevation contours	GLIN
Bathymetry	lake_ontario_bathymetry	line	Lake elevation contours	GLIN
Bathymetry	lake_saint_clair_bathymetry	line	Lake elevation contours	GLIN
Bathymetry	lake_superior_bathymetry	line	Lake elevation contours	GLIN
ENC_Data	BeaconLateral_Approach	point	Potential for sensor placement	NOAA
ENC_Data	BeaconSpecialPurposeGeneral_Approach	point	Potential for sensor placement	NOAA
ENC_Data	BeaconSpecialPurposeGeneral_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	BuoyCardinal_Approach	point	Potential for sensor placement	NOAA
ENC_Data	BuoyIsolatedDanger_Approach	point	Potential for sensor placement	NOAA
ENC_Data	BuoyLateral_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	BuoyLateralApproach	point	Potential for sensor placement	NOAA
ENC_Data	BuoySafeWater_Approach	point	Potential for sensor placement	NOAA
ENC_Data	BuoySpecialPurposeGeneral_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Daymark_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Daymark_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	FogSignal_Approach	point	Potential for sensor placement	NOAA
ENC_Data	FogSignal_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	LightFloat_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Lights_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Lights_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	OffshorePlatform_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	Pile_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Pile_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	RadarTransponderBeacon_Approach	point	Potential for sensor placement	NOAA
ENC_Data	RadarTransponderBeacon_Coastal	point	Potential for sensor placement	NOAA
ENC_Data	RetroReflector_Approach	point	Potential for sensor placement	NOAA
ENC_Data	SignalStationTraffic_Approach	point	Potential for sensor placement	NOAA
ENC_Data	Topmark_Approach	point	Potential for sensor placement	NOAA
Hydro	GreatLakes	polygon	Cartography	LTI
Hydro	hydline	line	Cartography	LTI
Hydro	hydpoly	polygon	Cartography	LTI
MonitoringStations	AnnoMaskActiveLakeMichSouth	polygon	Cartography	LTI Generated
MonitoringStations	AnnoMaskNotActiveLakeMich	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1175000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1175000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1300000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1300000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1500000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno1500000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno900000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeActiveAnno900000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeMonitoringSites	point	Existing Real Time Monitoring Sites	NOAA/GLERL
MonitoringStations	RealTimeNotActiveAnno1175000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno1175000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno1300000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno1500000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno1500000Mask	polygon	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno900000	annotation	Cartography	LTI Generated
MonitoringStations	RealTimeNotActiveAnno900000Mask	polygon	Cartography	LTI Generated
MonitoringStations	WaterhsedWaterLevelGages	point	Existing Real Time Monitoring Sites	USGS/Environment Canada
MonitoringStations	WaterQualityMonitoringStations	point	Existing Routine Monitoring Sites	Environment Canada/EPA-GLNPO/MDNRE

Table 1: GIS Data Summary

Feature Dataset	Feature Class	Feature Type	Purpose	Source
Political	CanadaCityLimits5miBufferGreatLakes	polygon	Cartography	LTI Generated from ESRI data & maps DVD
Political	CanadaCityLimits5miBufferGreatLakesAnno1175	annotation	Cartography	LTI Generated
Political	CanadaCityLimits5miBufferGreatLakesAnno1175	polygon	Cartography	LTI Generated
Political	CanadaCityLimits5miBufferGreatLakesAnno1500	annotation	Cartography	LTI Generated
Political	CanadaCityLimits5miBufferGreatLakesAnno1500	polygon	Cartography	LTI Generated
Political	CanadaCityLimits5miBufferGreatLakesAnno9000	annotation	Cartography	LTI Generated
Political	CanadaCityLimits5miBufferGreatLakesAnno9000	polygon	Cartography	LTI Generated
Political	States	polygon	Cartography	ESRI data & maps DVD
Political	UrbanAreas5miBufferGreatLakes	polygon	Cartography	LTI Generated from ESRI data & maps DVD
Political	UrbanAreas5miBufferGreatLakesAnno1175000	annotation	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno1175000M	polygon	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno1300000	annotation	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno1300000M	polygon	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno1500000	annotation	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno1500000M	polygon	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno900000	annotation	Cartography	LTI Generated
Political	UrbanAreas5miBufferGreatLakesAnno900000Ma	polygon	Cartography	LTI Generated
Political	ZipCode_Poly_ESRI	polygon		ESRI data & maps DVD
Shipping	NationalWaterwayNetwork	line	The National Waterway Network (NWN) is a geographic database of navigable waterways in and around the United States, for analytical studies of waterway performance, for compiling commodity flow statistics, and for mapping purposes.	http://www.bts.gov/publications/national_transportation_atlas_database/2009/
Shipping	USGL_Port_and_Waterways_Facilities	point	Physical characteristics and infrastructure data for port and	GLIN
Shipping	USGL_Principal_Ports_2005	point	Physical characteristics and infrastru	GLIN
Transportation	interstates	line	Cartography	ESRI data & maps DVD
Watersheds	GL_ShedInOut	polygon	Cartography	LTI Generated
Watersheds	HUC12_GL	polygon	Great Lakes Watershed 12 Digit HUC	USGS
Watersheds	HUC_Dissolve	polygon	Great Lakes Watershed boundary	USGS
Watersheds	Quaternary_wusp2	polygon	Ontario Watershed Boundaries	LTI
	grtlks_depthm	Raster Dataset	Water depth (Meters) of the Great La	LTI Generated from the Great Lakes contours downloaded from (http://gis.glin.net/ogc/services.php?by=topic)
	landcover28	Raster Dataset	Ontario Land Cover Data Base	Geomatics and Data Acquisition Services Section Natural Resources Information Branch Ontario Ministry of Natural Resources 300 Water Street, 2nd Floor Peterborough, Ontario K9J 8M5
	MappingAreaCLIP	polygon	Cartography	LTI Generated
	nlcd_mosaic	Raster Dataset	2001 National Land Cover Dataset	http://datagateway.nrcs.usda.gov/

6. OCEAN OBSERVATORIES INITIATIVE (OOI)

The National Science Foundation (NSF) Ocean Sciences Division is developing the Ocean Observatories Initiative (OOI) which combines state of the art ocean observation systems with sophisticated cyber-infrastructure (CI) to support scientific research. The project is currently in the construction phase (5 years), with the CI component scheduled to be complete by 2014. Release 1 of the CI is scheduled for 2011.

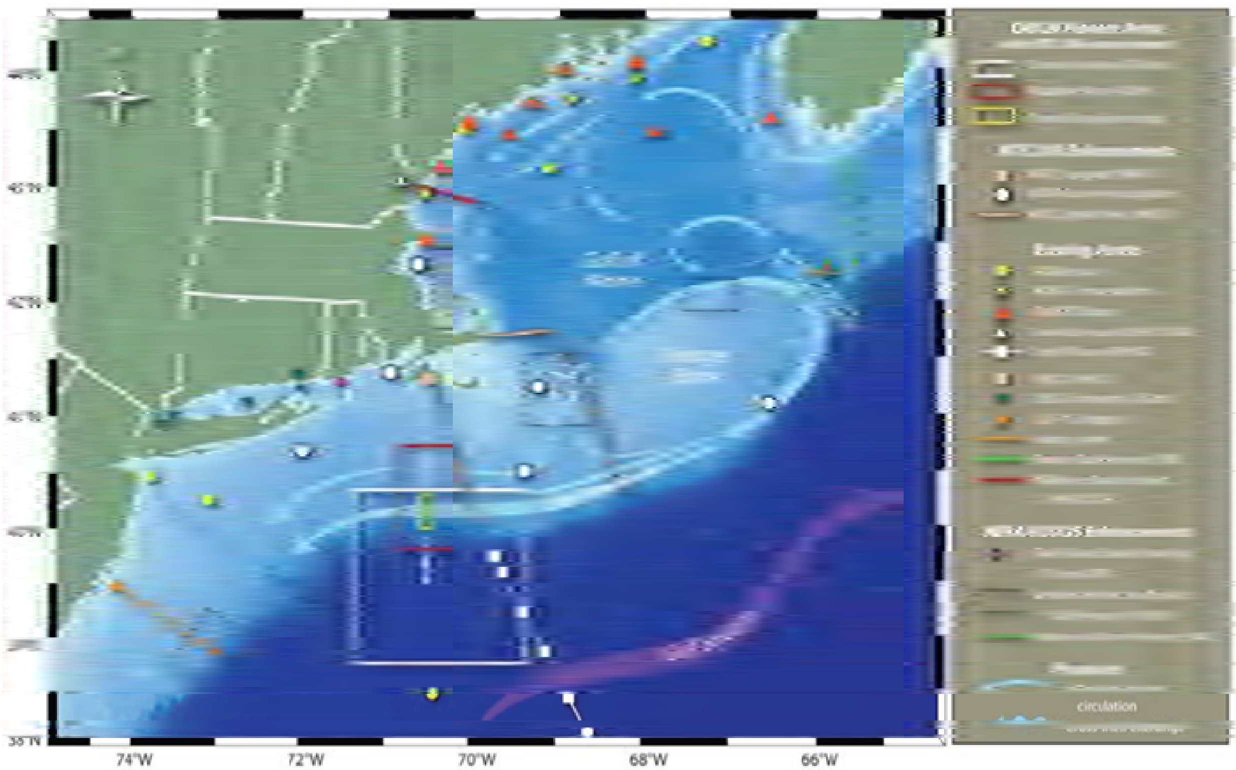

Figure 4. Vision for combined OOI and IOOS assets (courtesy NSF)

The OOI consists of multiple integrated systems that provide sustained, high-quality measurements of many air-sea, ocean, and seafloor parameters across a range of spatial scales. The integrated system will permit scientists to apply these data to a wide range of scientifically and socially critical topics in areas as diverse as climate change, ocean acidification, ecosystem health, carbon cycling, and seafloor volcanism that supports novel life forms, while also providing essential time series observations of multiple ocean processes and providing the capability to detect specific short-lived events (e.g. earthquakes, storms, plankton blooms). This system of systems consists of fixed and mobile platforms at multiple locations, with each platform designed to support a broad array of sensors, all connected and controlled via a sophisticated communications and computation framework.

Observatory resources of different type and purpose need to be administered, including:

- Observation Plans, providing activity sequences, service agreements and resource allocations for observational campaigns, and similar templates for event-response behaviors;
- Data Sets, representing observational and derived data and data products in the form of data archives and real-time continuous data streams;
- Processes, representing data collection and processing workflows that arrange multiple steps involving multiple actors and resources;
- Instruments and marine observatory infrastructure elements, such as telemetry systems, GPS and data loggers;
- Models, including numerical ocean forecast models and their configurations, as well as other analysis and event detection processes;
- Knowledge, representing all metadata, ancillary data, analysis results, association and correspondence links between resources, and knowledge captured in ontologies for semantic mediation purposes.

And to accomplish this, the OOI-CI is being built, essentially from the the ground up, although leveraging a number of existing technologies and standards. The OOI CI is structured into six subsystems:

Table 1. OOI CI Subsystem Structure

Subsystem	**Subsystem Type**
Sensing and Acqusition	Application Supporting Subsystem
Data Management	Application and Infrastructure Supporting Subsystem
Analysis and Synthesis	Application Supporting Subsystem
Planning and Prosecution	Application Supporting Subsystem
Common Execution Infrastructure (CEI)	Infrastructure Subsystem
Common Operating Infrastructure (COI)	Infrastructure Subsystem

The cyberinfrastructure is designed to provide truly end to end data management, from the sensor communications, qa/qc, transformation, to the delivery of data and analysis to the end user.

These services sit within the Common Operating Infrastructure (COI), the subsystem that provides the set of services and integration framework, and the COI in turn relies on the Common Execution Infrastructure (CEI), an elastic computing environment of virtual storage and processing that scales on demand. The OOI may not host the actual hardware and software as it is designed to operate on a target environment such as Amazon EC2.

The system is designed so the end-user is also a contributor, for example a modeler that consumes data from the OOI-CI and publishes results back into the OOI-CI.

A number of cross fertilization projects between OOI and IOOS are already underway, specifically use case 1, which is integration with a modeler (John Wilkin, Rutgers, Mid-Atlantic) as part of the External Observatories Integration (EOI) task.

Primary Objectives:

- Provide data to modelers via standardized, reliable and efficient services.

- Provide high level scientific access to the data services. Matlab will be used for an initial protoype but the lessons learned will be expanded to other common analysis tools such as R or Python.
- Provide command line access to the data services (i.e. NCO).
- Assess and provide feedback on the Unidata Common Data Model (CDM) new feature types for points, time series, profiles and trajectories.

Bonus (or secondary) Objectives:

- Provide a subscription pull service so the data can be as timely as possible.
- Provide an aggregation service
- Assist with getting RA's glider observational data into the OOI-CI and then possibly onto the GTS.

We suggest that this effort should be reviewed closely in this Great Lakes design project as an example of how an external observatory (Great Lakes) can leverage and connect to the OOI-CI.

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7. RAYTHEON IOOS CONCEPTUAL DESIGN (2006)

The Raytheon Team generated a Conceptual Design for IOOS. It incorporates three primary elements from a "logical" perspective:

Assets

The Design is application agnostic. This means any collection of assets can be integrated into the enterprise based upon national/local priorities and budgetary considerations.

Horizontal Integration (HI) Components

Asset integration is supplied by five distinct "levels of integration" offering simple to complex modes for asset integration. The HI components allow assets to be integrated in a variety of ways making the system dynamic. The level selected for the integration of a specific Asset into the IOOS Enterprise may be specified by requirements, or it may be determined by the results of a cost/benefit trade study taking into account feasibility, cost, and performance.

Basic Architectural Support Services

The IOOS Conceptual Design provides a set of basic architectural support services to manage some of the following across the IOOS enterprise:

- Communications
- Security
- Workflow
- System status

These services are provided within a loosely coupled Services Oriented Architectural (SOA) framework as depicted below

LimnoTech
Water | Environment | Scientists | Engineers

Technical Memorandum 1: Current State of Data Management in Support of Observing Systems

Near-Term Design of the Great Lakes Observing System Enterprise Architecture

June 30, 2011

Prepared for:

NOAA-GLERL
(Contract Number: WC133R-10-CN-0350)

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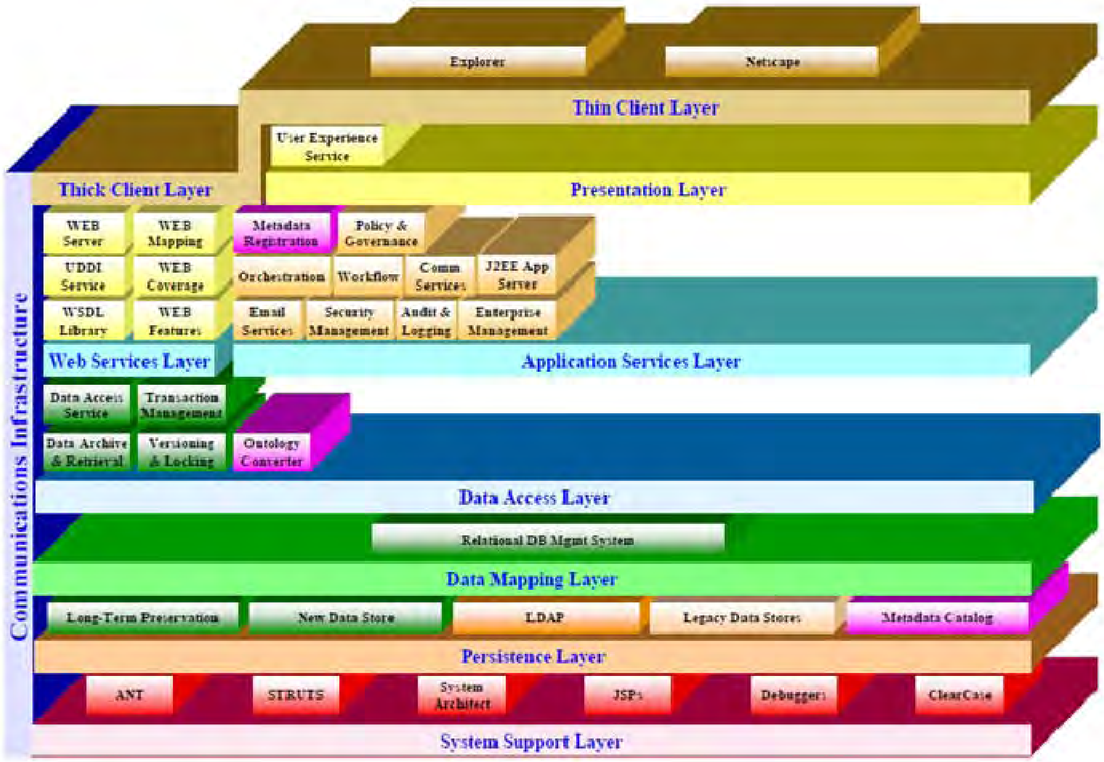

Figure 5. Services Oriented Architectural (SOA) Framework

7.1 PHYSICAL REPRESENTATION

A Physical Representation of IOOS contains the following elements:

Assets

The IOOS development plan was revised and 365 unique assets were identified for integration. Each asset was given an integration level based upon the conceptual design system.

Horizontal Integration (HI) Components

In the physical design they become tangible when they are used to integrate assets

Portlets

Technically are a part of the HI components because they are the primary entry point for users into the IOOS Enterprise. They provide a unique interface for a community of interest to access the IOOS Enterprise allowing them to view a single set of assets. This allows for the exploitation of data in vastly different ways by different end users. They are a key element of IOOS Enterprise.

Common Services

The same version of the Basic Architectural Support Services is installed at each IOOS node. Thus, these services are "common" across the enterprise. The architectural design allows each node to integrate whatever assets they feel appropriate (local autonomy) yet the commonality of the services ensures all assets are exposed and available to the entire enterprise.

Regional Integration Nodes

It is a physical node hosting an instance of the IOOS common services and the HI components supporting the assets being integrated through that node. All RINs form a network and are aware of each other. A RIN consists of servers in a physical facility running an instance of the software represented by the conceptual design.

National Backbone

It is logically defined as all of the assets required for the federal agencies to fully meet their mandates IOOS-related service to citizens. Physically it is a Multi-protocol Label Switching (MPLS) Network which provides the physical infrastructure for RIN interoperability.

Integration Points

In cases where latency and performance issues can be adequately addressed, it may be more cost effective to integrate multiple assets at a single “integration point” rather than integrating all of them separately. Conversely, to address both performance and quality issues, it may be necessary to integrate a specific IOOS Asset at multiple integration points. For example, many IOOS global Assets find their way to the National Data Buoy Center (NDBC) for QA/QC,

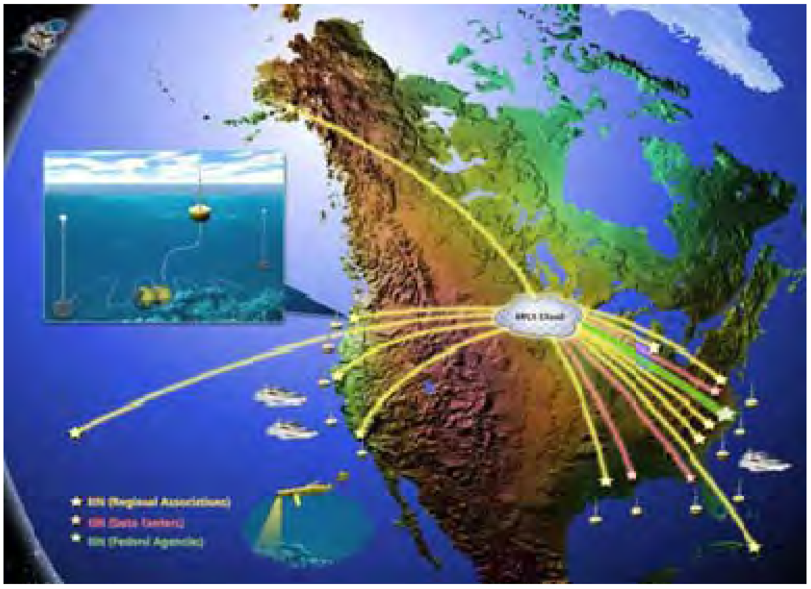

Figure 6. Representation of IOOS Enterprise

7.2 ADVANTAGES:

Flexibility – The application-agnostic nature of the design offers flexibility in determining which assets need to be integrated into the enterprise

Scalability – At present the system is complex and a consumer of data must be aware of sources and access those sources in a point to point fashion. This solution scales poorly so moving towards horizontal integration method the scalability can be improved drastically. In this conceptual design HI components are used to integrate source assets or Ocean Observing and Telemetry (O&T). A metadata catalog supports data discovery and access. Then another HI component is used to transform the data so it can be ingested by the exploitation assets or Data

Analysis and Modeling (DAM). These HI components are data resource adapters (DARAs) that have no impact on the assets they serve. Thus, this solution scales quite easily.

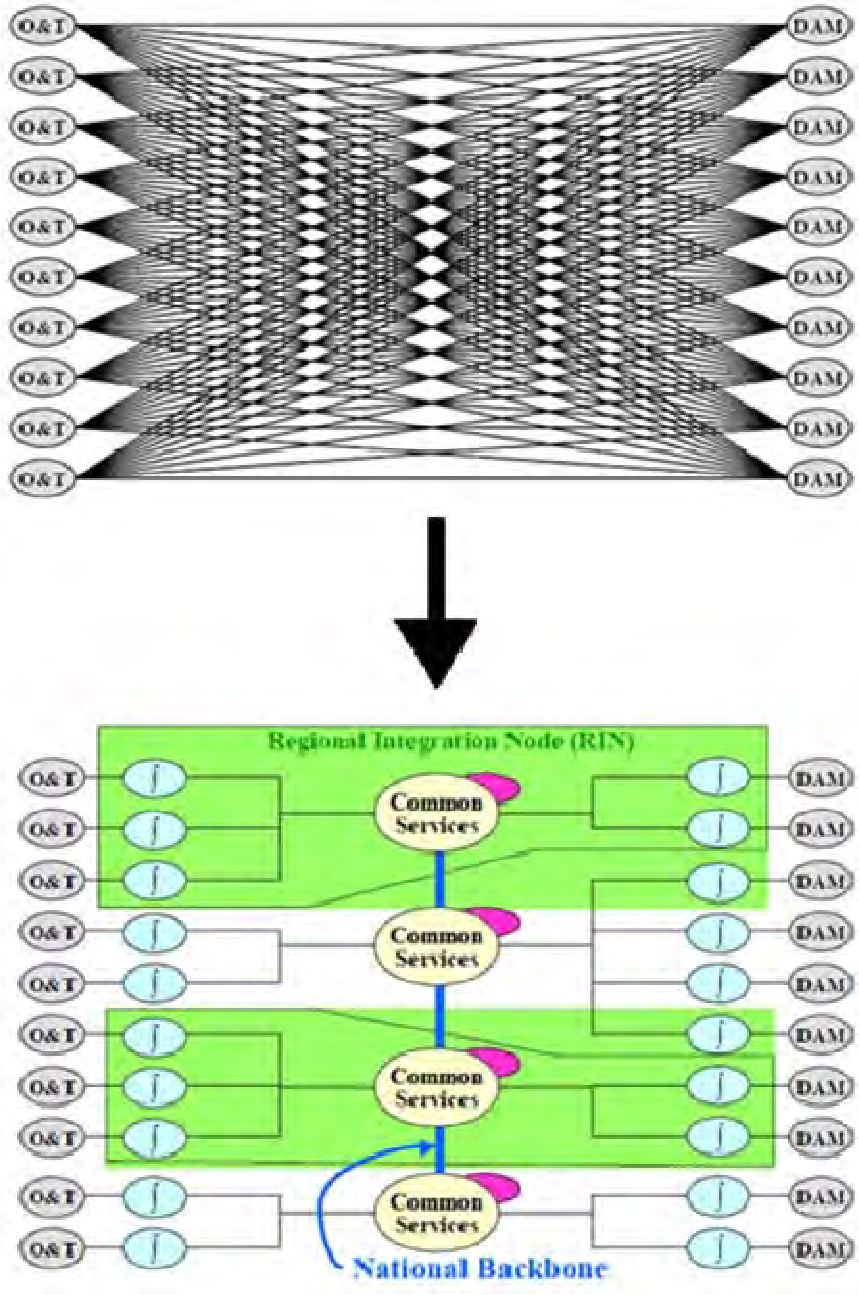

Figure 7. Transition towards a Horizontal Integration (HI) Approach

8. LOCKHEED MARTIN IOOS CONCEPTUAL DESIGN (2006)

The Lockheed Martin Conceptual Design for IOOS was driven by looking at the functionality in relation to the user and the provider. The system was conceptually designed in terms of how the user would make use of IOOS and how the provider would offer data to it. This is outlined below:

8.1 USER PERSPECTIVE

Users of IOOS have one major objective: to obtain the data that they need for their application. In order for IOOS to enable a user to meet this objective, it must allow them to discover and obtain the data. For the less experienced users, there should also be an educational component to the process so that a user can understand the data and its applicability. There are three entry points through which a user will discover and gain access to IOOS data: via an IOOS portal, through a DAC website, or directly from the data provider. Each of these entry points are discussed below.

8.2 IOOS PORTAL

The IOOS portal is envisioned to provide any IOOS user with a trusted point of entry for discovering and obtaining any and all IOOS data. A user will access the portal and utilize the data discovery service to search for data. Users will be able to search for data that meets temporal, spatial, and/or thematic criteria. These search criteria will be used to query the IOOS database which has been populated with metadata records. The search results will be retrieved by the data discovery service and displayed in the portal. Once in the portal, the user can sort through their search results, view metadata about their search results, and identify data for download. In identifying data for download, a user will be able to specify the format and any subsets of the data that they desire. This information is relayed to the data transport service which, using the information contained in the metadata record, knows where to go to retrieve the data. The data that is retrieved could come from either a DAC long-term archive or short-term repository or also directly from a provider’s database. Regardless of where the data comes from, it is delivered to the user, in this instance, by the data transport service through the IOOS portal interface.

8.3 DAC

Access through a DAC will be very similar to access through the IOOS portal and will utilize many of the same services. Through a DAC, a user will be able to discover, learn about, and obtain data; however, there may be some services that are customized from a generic service to meet the requirements of the respective DAC. The differences between access through a DAC and the IOOS portal are highlighted below:

- The access point for a user through the DAC will be through a DAC-specific website vice an IOOS portal. This access point will be owned and maintained by the DAC. This website will link to a reusable IOOS data discovery service and also a reusable data transport service.
- The catalog that is searched from the DAC is a locally-maintained catalog. A locally maintained catalog will reuse the standard IOOS catalog but may have some specific customized features. For example, a catalog for a satellite data DAC may be founded on one standard that is relevant to satellite data and imagery while a catalog for an ecosystem data DAC may employ a slightly different standard relevant to its data. An important aspect of a DAC catalog is that it must be synchronized with the overarching IOOS catalog.
- The final difference between the DAC path and the IOOS portal path is that a DAC will have locally maintained data holdings. If a user goes directly to a DAC for data, the data transport service will obtain data from the local DAC holdings.

8.3.1 Provider

There are two methods by which a user can access data directly from a provider. In both cases, the user accesses the data directly from the provider's website but the difference is in how the user discovers the provider's site. The user could discover the provider's data through the IOOS portal and discover services; however, after learning about the data in the discovery results, the user could decide to go directly to the provider's site and no longer use the IOOS services. Most metadata formats contain a field for listing the uniform resource locator (URL) for the data and this could be the launch mechanism that gets a user to the provider's website. The other way for a user to discover a provider's data is outside the realm of IOOS services using traditional search engines. Any of the Internet's search engines will return a list of IOOS-related observing and modeling programs with the right keywords. While not a mechanism considered as part of this conceptual design, this method of discovery will persist for more knowledgeable users with or without the creation of IOOS and therefore should not be ignored.

8.3.2 Provider Perspective

A provider has a fundamental desire and responsibility to make their data available to the user community. Much like a user will have different options for discovering and obtaining data, a provider will have options for publishing and distributing their data but generally through the same paths which a user may access data: the IOOS portal, a DAC, or directly from the provider.

8.3.3 IOOS Portal

A provider will publish their data through the IOOS portal and services using a specific path. The provider will perform assembly and quality control of their data locally; however, they can leverage and utilize IOOS's quality control services to perform this same task. Once a dataset is prepared for publication, the provider will employ IOOS's metadata management service to create the applicable metadata about their dataset and then load that metadata to the IOOS catalog service. At this point, the data will be discoverable via the IOOS portal. As the metadata is published, the provider will move the actual data to their own local repository. This repository could take many forms including, for example, FTP directories or database applications. An important link in this process is established by publishing the location of the data in the local repository within the metadata in the IOOS catalog. This linkage will enable the data transport service, if called upon to retrieve the data by a user, to locate the data. The key feature of this method of publishing data to the IOOS community is that the provider will still retain ownership of the data.

8.3.4 DAC

The DACs will provide an optimal method for publishing and distributing IOOS data. Under the DAC concept, a provider will turn over their data to the DAC who will assume responsibility for quality control, metadata creation and publication, the short- or long-term storage of that data, and supporting the discovery of and access to the data. The DAC would either utilize standard IOOS services to perform these business functions or could employ customized services that are more relevant to the particular type of data for which the DAC is responsible. Such customized services will comply with IOOS standards at the public interface point. Using a DAC will allow a provider to focus strictly on the business of collecting, in the case of observations, or producing, in the case of models or analyses, their data. This approach would be most attractive for providers who lack the infrastructure to assume the overhead data management business functions that would otherwise be performed by the DAC. However, releasing data to a DAC would not preclude a provider from publishing their data on their own or using the IOOS portal.

8.3.5 Provider

Publishing data through the IOOS infrastructure is completely optional for providers who could also publish their data and make it available through their own infrastructure. The provider would perform their own data assembly and quality control locally either by using IOOS reusable services or by using some proprietary methodology. At this point, the provider would publish the fact that this data is available through their website. While this could be accomplished with reusable IOOS metadata and catalog services, it could also be something as simple as a link on their webpage. The data itself will move to a local repository and be accessed via a link on the provider’s website. Because this process occurs completely outside the realm of the IOOS discovery services (either general IOOS or a DAC), it could only be discovered by the general user community if it appears in an Internet search engine or the user had previous, personal knowledge of this provider.

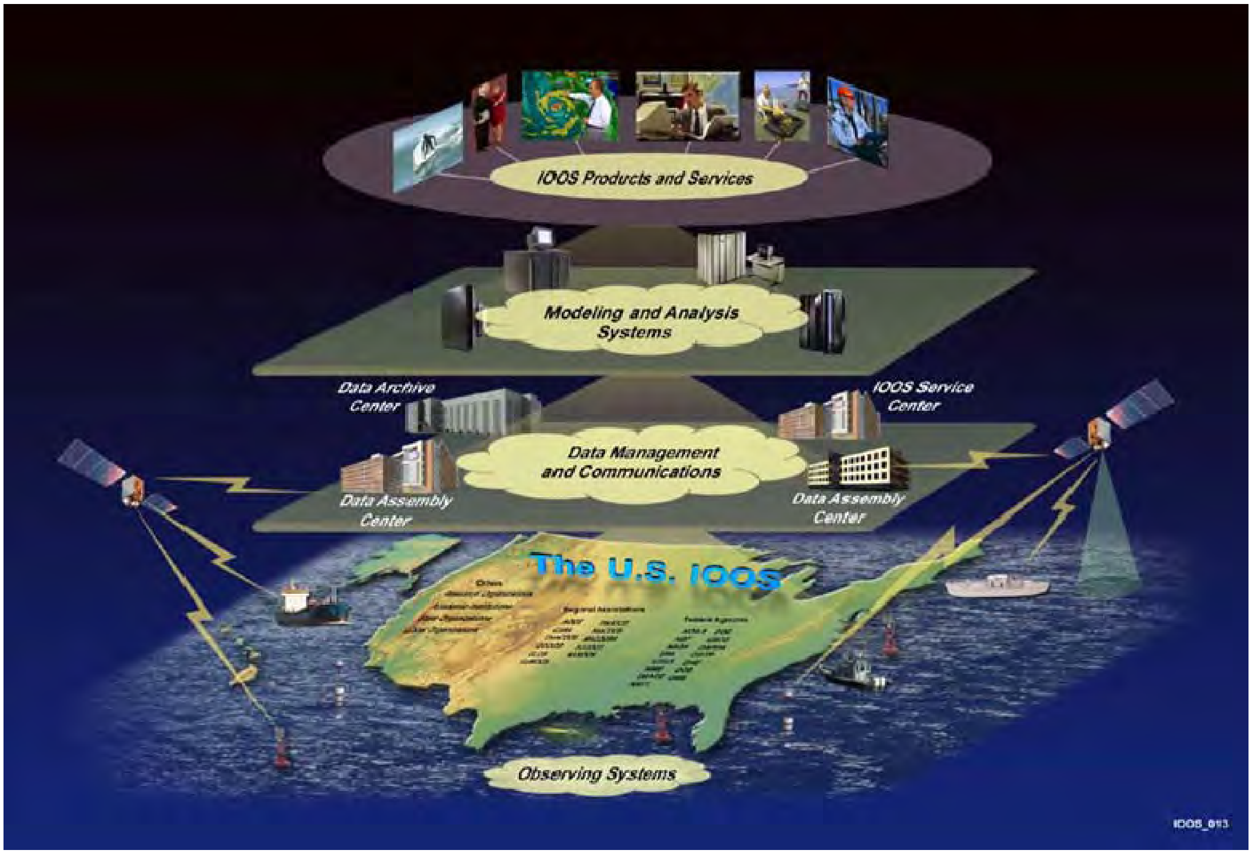

Figure 8. IOOS Enterprise Components

8.4 IOOS SYSTEM SERVICES

IOOS system services are the services that will be operated on physical hardware and software systems located in a number of physical IOOS facilities. These physical systems and facilities are envisioned to primarily be re-using of existing systems and facilities with enhancements to support IOOS as needed.

Below is the list of IOOS system services that are required in the IOOS framework:

Security Services

IOOS Security Services are specified under the guidelines of FISMA and relevant NIST standards. Several services components defined for delivering the basic functions for IOOS operation. It is envisioned that there will be many security controls needed after the establishment of a comprehensive IOOS security plan under the oversight of IOOS governance. Security controls ensure the protection of IOOS information networks and systems. Proper data encryption and system monitoring will be required. Additional controls may also be required if there is sensitive information passing over public networks.

Data Storage Services

Data Storage Services support IOOS data persistency and data storage management. Data Storage Services are envisioned to be distributed to different physical locations, given that IOOS is and will be a federated system of systems. Leveraging existing data storage assets will be encouraged, especially for those large scale data storages facilities such as Data Archives centers.

Sensor/Data Acquisition Services

These services are directly responsible for the acquisition of IOOS core variables and other observations. Sensing equipment or devices may include:

- Remote sensing instruments on aircraft
- Satellites and land-based and water-based platforms
- Sensors in Situ on buoys.

The IOOS Data Collection Service will be used to provide the diverse set of acquired observations originating in different formats, in a manner that conforms to IOOS data and metadata standards. The Data Collection Services can theoretically be implemented right down at the senor level (as in some next generation sensors) but are generally expected to be implemented at the DAC. The Data Collection Services hide the details of underlying sensor technology and thereby support on-going enhancements of sensors and observing platforms without any negative impact on IOOS users of these services.

Modeling and Analysis Services

These services are designated to address the IOOS final products for various mission objectives and business purposes. Appropriate and efficient facilitation of the services allows users and decision makers to strive toward the societal goals set forth by IOOS. Further effort at the system design level will be required to identify and define services components for additional business objectives.

Data Services

The IOOS Data Services are designed primarily to support data transport and data discovery. The main function is to obtain data from various sources and deliver data to a data consumer in a format and mechanism that conforms to IOOS standards. The data consumer can be either other IOOS services components or an end user. The Data Services utilizes different data standards interacting with Data Standard Services and metadata Interoperability Services.

Portal Services

The IOOS Portal Services serve as the window of access to all IOOS products and services to general public and other users. It will be considered as the authoritative source for IOOS information. The IOOS portal is envisioned to support advanced portal features such as single sign-on capability for authenticated users to access various IOOS services.

Data Communication Network

The IOOS Data Communication Network is envisioned to leverage stakeholder data communication facilities, commercial communication facilities and the Internet. Major IOOS facilities may additionally have dedicated communication links between them to meet specific requirements such as high bandwidth and high availability.

Interoperability Services

The Interoperability Service will provide translation functionality between multiple data standards that are expected to be used in IOOS. These services are also expected to be used IOOS's interface to external systems such as GOESS, GOOS and IEOS.

Data Collection Services

These Services support up-front acquisition and assembly of raw data from sensors and observing systems. They will utilize metadata management services for tagging the sensors and observing system data with a set of the IOOS standard metadata. Inconsistencies and/or discrepancies are flagged and a notification is sent to the data provider. This allows for an automated dissemination process that places datasets into the IOOS Data Storage Services as soon as they have been screened and validated. This in turn facilitates high-volume collection and permits the scientific study of the datasets to occur on an as-needed basis over time.

Enterprise Services

Enterprise services are a set of common service components that are required for all service components to function within the IOOS framework. These services are accessible to every service component within IOOS.

IOOS Notes Definition

An IOOS node is an IOOS standard interface class for establishing an IOOS services component. It contains a set of IOOS standard methods and attributes that brings an IOOS service component into the IOOS framework. It serves as the fundamental mechanism for exposing the functionality and data within an existing or new system into the IOOS framework. The IOOS node structure is illustrated in the figure below.

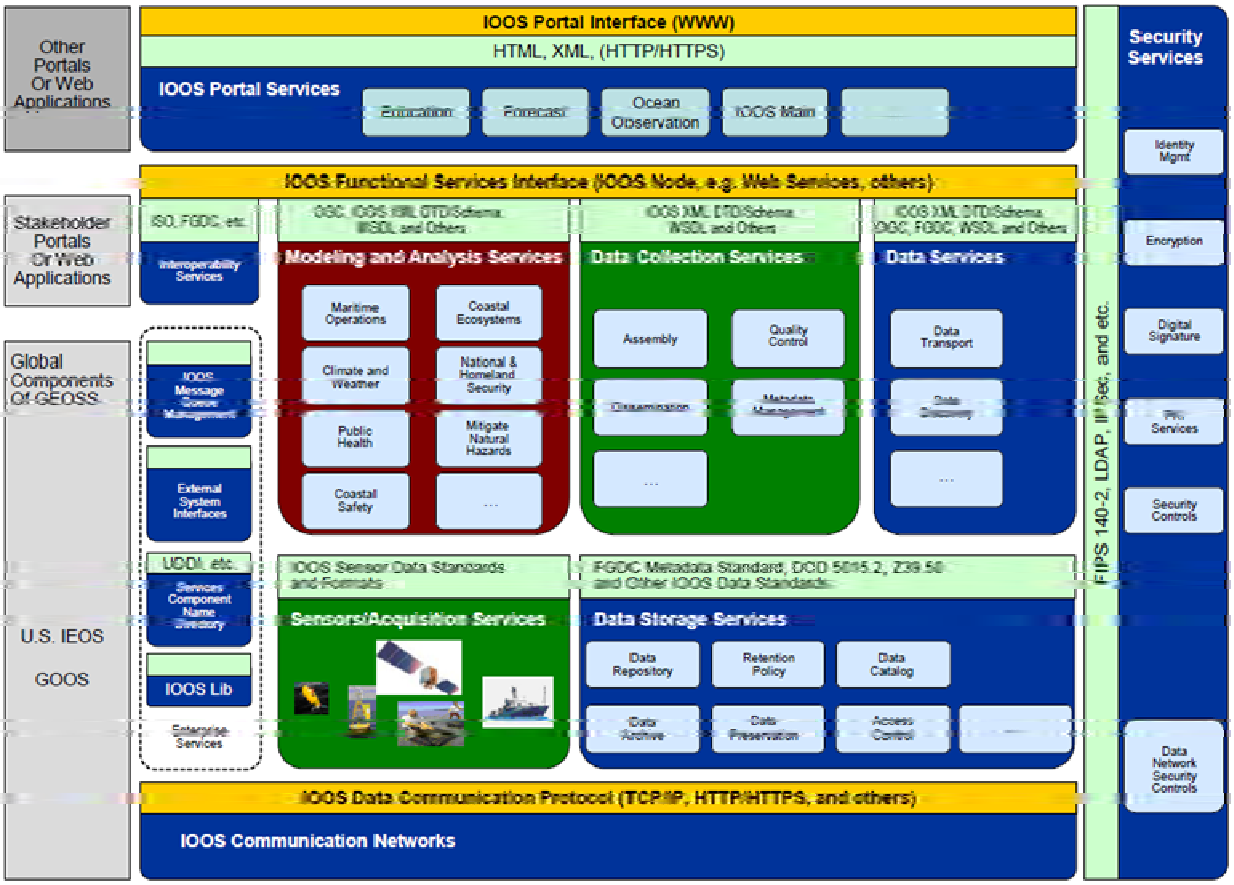

Figure 9. IOSS System Services and Interfaces.

This figure describes the IOOS system services and their interfaces. The highlighted rectangles in orange represent the IOOS system services interfaces. The standards of each service are portrayed in light blue.

8.4.1 Advantages:

While it is conceivable that a provider could get their data to the IOOS user community without the use of any IOOS services, there are inherent advantages to a provider employing the capabilities of the system outlined above. These advantages include:

Greater visibility

The IOOS and DAC discovery services will reach a much broader user community.

Greater acceptance

Use of IOOS-standard services will establish a certain level of trust and confidence in the data and the provider, particularly in the area of data quality.

Broader use

Exposing data through the IOOS services will promote broader use by users with diverse applications and data format requirements. Without IOOS services, the provider's data will remain within the system and largely inaccessible and unexploited.

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More efficient operations

Rather than having to create proprietary solutions, a provider can reuse IOOS services to serve their data to the user community.

9. U.S COAST GUARD ENVIRONMENTAL DATA SERVER

The US Coast Guard employs a Service Oriented Architecture based system to manage data required to drive the Search and Rescue planning system. The System is referred to as the Environmental Data Server (EDS). The EDS provides homogenous access to meteorological and hydrodynamic data via web services. It is designed to be scalable and modular and utilizes a Service Oriented Architecture (SOA). Users (clients) access the available data by using a web service (making an XML request to the server specifying what is needed), and the web service returns data based on the request. The web service may return data to the client from data products stored in distributed servers, or a more common approach is that the catalog server retrieves data to a central server as a background process so all the data is stored and archived on a central server. For mission critical applications that need archive and forecast data with very fast response times, this solution is preferred.

The EDS consists of three major sub-systems governing data collection (the Catalog Server), data storage (the Data store), and data distribution (the EDS web services).

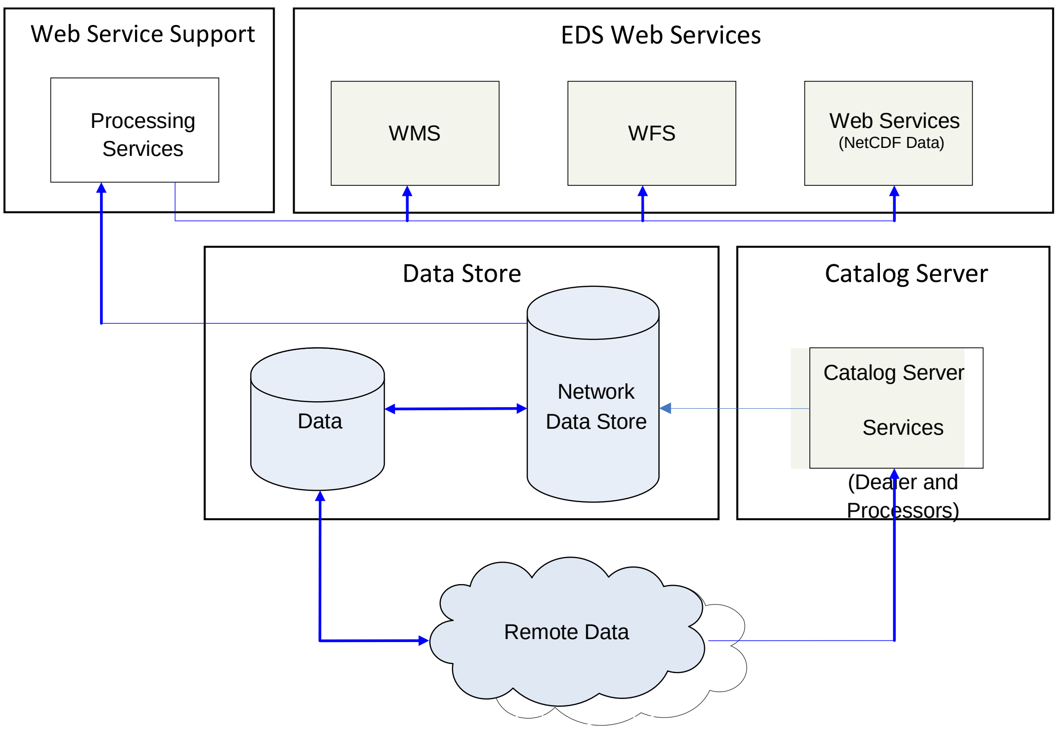

Figure 10. EDS High-level Architecture

9.1 CATALOG SERVER

The EDS process of data collection and cataloging services (collectively known as the Catalog Server) allows administrators to customize the data to be made available to their client applications.

The Catalog server is a series of data collection services governed by a timing service that automatically collect, process and store data from any number of disparate sources according to source availability schedules. The services use metadata stored in a SQL database that tell the catalog server when and from where to collect data.

The catalog server collects data via HTTP, FTP, or OpeNDAP and generally stores the data in its native format. The Catalog Server generally never changes the original data, and always maintains the native grid structure of the data.

Typical collection formats are NetCDF, GRIB (v1 & v2) and ASCII. The majority of the data managed by the EDS is gridded although some non-gridded data is also collected and distributed. The data collected includes:

- Gridded Observation data (Satellite, Sea Surface Radar)
- Numerical Model products (structured and unstructured grids)
- Point Observation data (NDBC, ADCP, Profilers, UUVs and UAVs)

9.2 DATA SERVICES

Three primary services that are available to client applications are:

- NetCDF Data Service
- OGC WMS Service
- OGC WFS Service

The EDS web services provide a catalog of the data available via XML as well as subsets of any of the data within the Data Store according to spatial and temporal parameters as well as client access privileges. A ranking (Quality) system may also be used so the user simply specifies a region, and an appropriate data set will be provided.

9.3 DATA STORE

The data store consists of two separate entities, the data catalog and the networked data store. The data catalog is housed in a relational database and includes system configuration information, rules for processing and data product specific metadata allowing for search functionality and itemizing available data resources. The networked data store is a file data store containing primarily NetCDF data, with some associated support files. The data store is the repository of information, both metadata and actual data.

10. U.S NAVY

The US Navy's Oceanographic Office (NAVOCEANO) is charged with the mission to collect, process, and distribute meteorological and oceanographic (METOC) products and data to the Department of Defense (DOD) and other national and international customers. At the highest level, NAVOCEANO is under the mandate to manage the information it provides according to the Net-Centric Data Strategy put forth by the Department of Defense.

"Net-centricity is the realization of a networked environment, including infrastructure, systems, processes, and people, that enables a completely different approach to warfighting and business operations. The foundation for net-centricity is the Department's Global Information Grid (GIG). The GIG is the globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, defense policymakers, and support personnel. Net-centricity, by securely interconnecting people and systems independent of time or location, supports a substantially improved military situational awareness, better access to business information, and dramatically shortened decision cycles. Users are empowered to better protect assets; more effectively exploit information; more efficiently use resources; and create extended, collaborative communities to focus on the mission." (Department of Defense Net-Centric Data Strategy, p.1)

METOC production centers dynamically populate their data stores with perishable environmental data. This is a process in which they ingest, update, archive and delete data on a regular, real-time basis. The management of the data flow into and out of these data stores is performed by numerous data storage systems and data management applications in disparate locations and environments.

In order to remain consistent with Net-Centric practice and to avoid the requirement for point-to-point application development, the US Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) and NAVOCEANO developed the data exchange standard interface known as the Joint METOC Broker Language (JMBL).

"JMBL is implemented in Extensible Markup Language (XML) and consists of a series of schema that define the structure of a request for METOC data and the structure of the associated response. JMBL allows each METOC data provider to offer a uniform interface for machine-to-machine access to METOC data on the GIG. " (METOC Data Management for Net-Centric Operations, p.2)

NAVOCEANO has also begun to implement Open Geospatial Consortium (OGC) Web services standards and specifications. OGC Web services are widely recognized and implemented for geospatial data access. Implementation examples include the use of Web Feature Services (WFS) utilizing Oracle Spatial

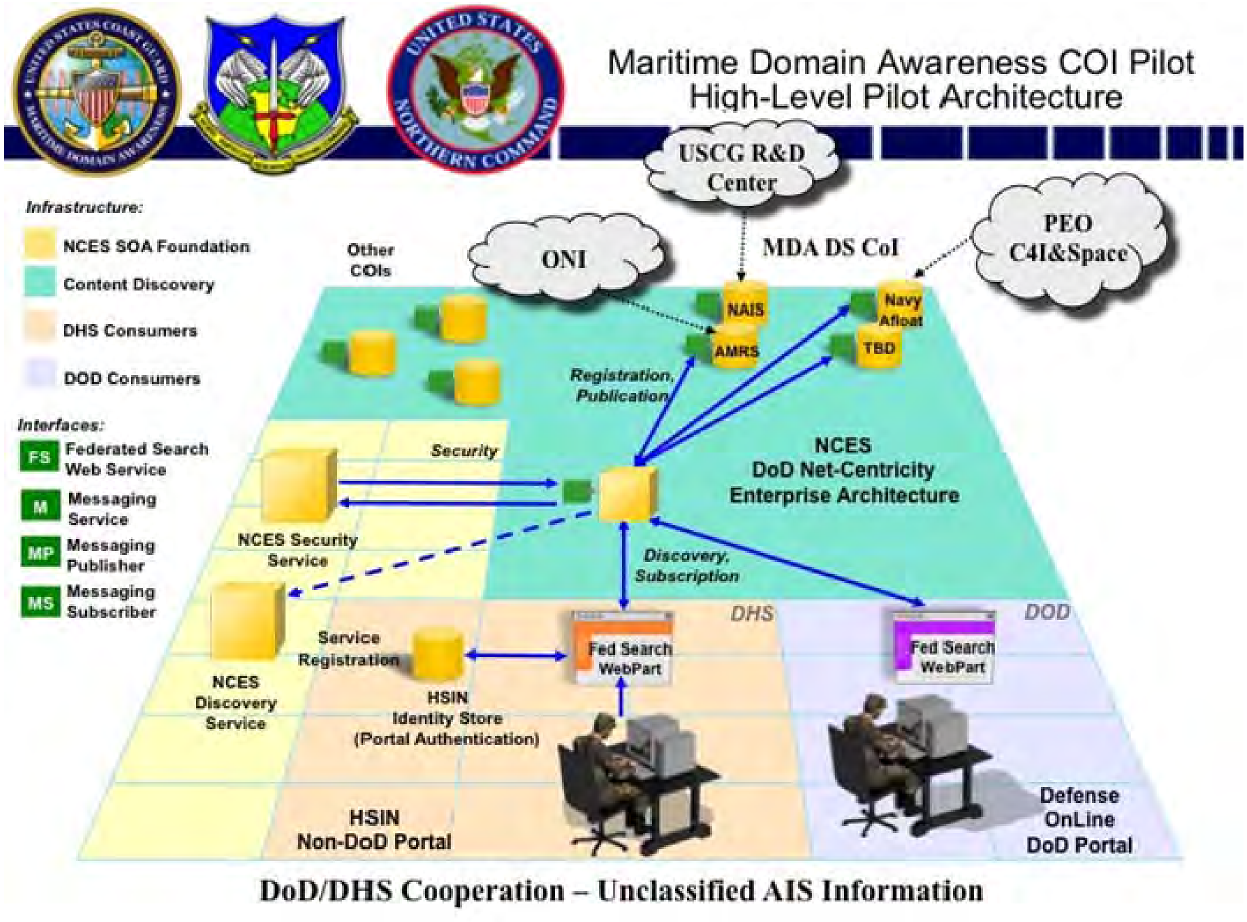

Figure 11. NCES Example Implementation Across Departments

11. HYDROLOGY/WATER QUALITY

Most of the discussion so far, both in this document, and in the IOOS community has been focused on physical parameters collected from in-situ devices, radar, satellite, and models. Although there is discussion in the IOOS community related to river discharge data and water quality, and connections to the National Water Quality Monitoring Council, the implementation of connectivity of hydrology and water quality data management in the IOOS regions is not as mature. This does not mean that this community does not have mature data management in place, but the integration of these two domains is still developing. There is communication between the agencies involved, water quality (EPA), hydrology (USGS), and physical oceanography (IOOS), and steps are being taken to provide improved communications between these systems.

Significant accomplishments have been made to integrate the hydrology and water quality community through a number of efforts, including OGC, the Consortium for the Advancement of Hydrological Sciences Inc. (CUAHSI), and a collaboration between USGS and EPA through the Data Exchange project. The CUAHSI group have invested considerable effort in developing standard web services to access hydrologic data and have built tools to connect these data to the GIS community through tools such as ArcHydro.

The Data Exchange effort has built a common suite of web services to improve sharing of water monitoring data via a common format and terminology. The services provide the ability to combine data from USGS's NWIS and EPA's STORET systems. The services produce data formatted according to the Water Quality Exchange (WQX) Outbound XML schema, which was developed collaboratively by EPA and USGS.

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12. CONCLUSIONS

- There are considerable investments in on-going programs related to data management for coastal and ocean observing, both at the federal and regional level.
- There are a number of standards initiatives in place, with a wide variation in the maturity level of the standards implementation process.
- There is generally consensus on standards within a domain or community, but weakness in cross-domain standardization and protocols. This includes the differences between groups such as the atmospheric community and oceanography community as well as observation groups within a domain, e.g. in-situ observations versus satellite
- For the most part, data management for in-situ sensors has been considered from the base station with the vendor's proprietary software to the data center and there is still a lack of common protocols for communicating directly with different vendor's sensors directly, despite efforts such as SWE (Sensor Web Enablement)
- There continues to be a significant challenge related to registration of data and searchable catalog(s)
- Related to the catalog issue, there continues to be no practical methodology for managing metadata
- Data providers, especially those involved in non-continuous observations (cruises, beach sampling) lack guidance and common protocols for submitting data to a data center
- The systems generally rely heavily on community participation and an "Open Source" culture
- There are no common gateways for accessing the disparate data with a wide range of domain specific web sites
- There remains considerable challenges in connecting the data and analysis products to end-users, including the GIS community that support policy and management
- The investment in OOI and its evolution could have an enormous impact on the observing community, but it is not clear to the community what the practical implementation of OOI will mean for them.

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13. ANTICIPATED NEXT STEPS

1. Summarize current status of these implementations, what works and what doesn't.
2. Summarize commonalities and differences of these approaches
3. Evaluate what common technologies and standards are used and what operational components can be leveraged from these and other systems
4. Discuss the practical implications of distributed versus centralization and data homogenization (common data model) versus sensor or variable specific data models
5. Outline the practical implementation of the proposed architecture and functional components to meet the Great Lakes observing requirements from the other work groups with specific recommendations for :
   a. In-situ observations (fixed)
   b. Moving point observations (gliders, cruises, etc.)
   c. Satellite
   d. Radar
   e. Models
   f. Static Geospatial Data (GIS)

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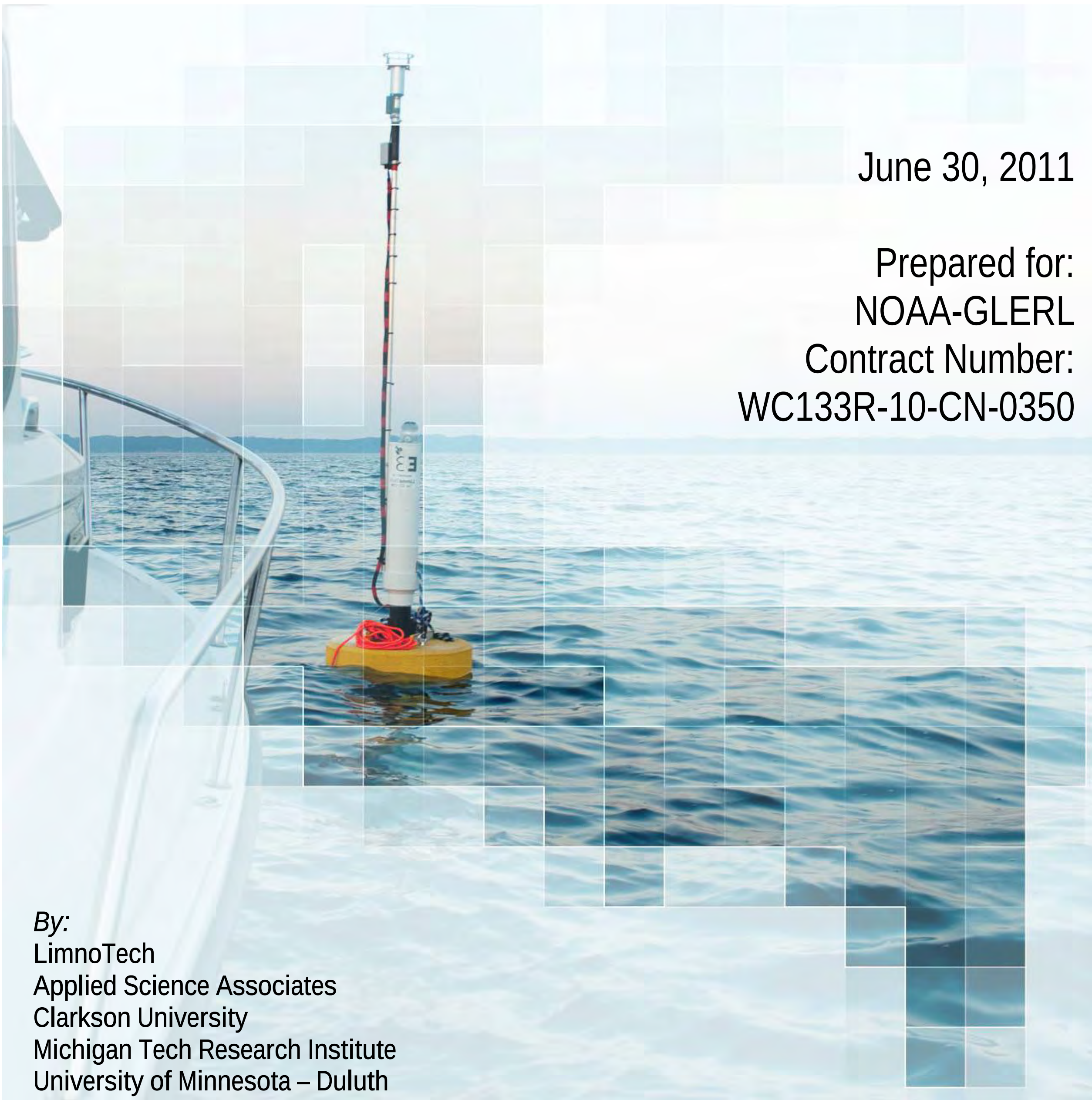
TECHNICAL MEMORANDUM 2: SUMMARY OF COST DATA FOR OBSERVATION SYSTEMS

Near-Term Design of the Great Lakes Observing System Enterprise Architecture



June 30, 2011

Prepared for:
NOAA-GLERL
Contract Number:
WC133R-10-CN-0350

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Technical Memorandum 2: Summary of Cost Data for Observation Systems

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1. INTRODUCTION

This memo is the third technical memorandum in a series of six that summarizes the current observations systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six tech memos cover the following topics:

1. Current state of data management in support of observing systems
2. Cost associated with observing systems
3. Inventory of Great Lakes observing systems and monitoring programs
4. Summary of Great Lakes DMAC infrastructure
5. Great Lakes models, scale, and operational status
6. Catalogue of Great Lakes user needs

Each of these tech memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

1.1 OBJECTIVE

The purpose of this memo is to document resources that have been identified that will assist in providing cost estimates for various system alternatives. Additionally, rough cost estimates from various sources are included to provide the reader with ballpark estimate of costs for various components of the observing systems.

1.2 APPROACH

This memorandum has been divided into sub-sections based on the major components of the anticipated GLOS enterprise architecture: Observation Systems, Data Management and Communications, Modeling and Analysis, and Education and Outreach. The focus of the memorandum is observation technology costs, as the other components' costs will be largely personnel driven. Personnel costs will be better estimated after more specific alternatives are developed.

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2. OBSERVATION TECHNOLOGY COSTS

This section will address capital costs, operational costs, and data transmission for various types of observations methodologies.

2.1 FIXED PLATFORMS:

The current GLOS ad-hoc network does not include fixed platform sites, however other IOOS member organizations Costs for operations of observation sites that include fixed platforms are available in the MARACOOS Years 1-5 budget estimate and the FY2011 budget breakdown. A major component of the MARACOOS is the operation of 35 CODAR Ocean Observation sites. These sites include both landside observatories and buoys. The MARACOOS Years 1-5 (MARACOOS, 2010) budget estimates site support at $10,000 per site, a technician budget of $300,000, and a regional coordination budget of $50,000. The total annual budget for operation of the CODAR sites is $700,000 or $20,000 per site. The MARACOOS FY2011 (Rutgers, 2009) budget is consistent with the Years 1-5 estimates. It also provides some additional detail regarding Wave Product for Long Range Network.

2.2 FLOATS AND BUOYS:

The National Data Buoy Center (NBDC) deploys and maintains a large number of buoys on the Great Lakes and in the coastal areas of the nations' oceans. Rex Hervey from that organization has indicated that they could deploy additional buoys in the Great Lakes for approximately $200,000 for the first year and $70,000 per subsequent year, dependent on the buoy configuration. He also indicated a willingness to provide more detailed cost estimates as the alternatives are developed.

GLOS held a workshop in October of 2009 with a number of organizations who currently operate observation systems in the Great Lakes. The proceedings of that workshop (GLOS, 2009) summarize capital and operating costs for each for each organization. The participating groups included the University of Minnesota Duluth Great Lakes Observatory (UMD), the University of Wisconsin Great Lakes Urban Coastal Observing System (GLUCOS), the University of Michigan Marine Hydrodynamics Laboratory (MHL), and the Great Lakes Environmental Research Laboratory (GLERL).

The buoy capital costs ranged from $18,000 to $42,000 depending on the platform, sensors, power, and data logging equipment. The annual operating costs ranged from $13,800 to $70,000 per buoy. For the groups that broke down the operating costs, personnel costs were approximately $25,000, shipping costs were $5,000, and data transmission fees were $500 annually. MHL noted two particular cost savings measures they had incorporated: using small vessels for buoy deployment and retrieval and the use of an MHL thermistor string that is significantly less expensive than commercially available models.

Clarkson University also put together a brief summary of buoy-related expenses based on their experience and resources. The buoys in the Clarkson summary are considerably more expensive than most of those currently deployed on the Great Lakes. The buoy cost estimates range from $165,000 to $382,000 depending on sensor and vertical profiling capability. Clarkson estimates the annual operating and maintenance cost at 20% of the capital cost.

As noted in the fixed platform section, the MARACOOS budget includes approximately $700,000 for the maintenance of their CODAR sites, which includes some floating stations. Also, SECOORA budgeted $500,000 for the maintenance of their moored and coastal observation sites.

Additional resources for determining costs include commercial providers of equipment and services. The GLOSEA team has assembled an inventory of commercially available platforms and sensors. A table summarizing key aspects of that inventory is presented as Table 2. It should be noted that cable length can be an important factor in sensor cost, indicating that collecting measurements at depth can be a driver of sensor costs.

2.3 SHIP-ATTACHED SENSORS

Ship attached sensors may be attached to research vessels with the sole purpose of collecting measurements, or they may be attached to vessels of opportunity, such as ferries. For both of these measurement types, the sensor capital and maintenance costs will be the primary expense. The costs developed as part of the buoy cost investigation will be useful for estimating ship-attached sensor costs. For vessels used exclusively to collect GLOS measurements, shipping costs will also be considered. The team will rely on the experience of the University of Minnesota-Duluth group regarding cost estimates for a tow-behind buoy.

2.4 SATELLITE OBSERVATIONS

MTRI has assembled a preliminary list of available satellite products for the Great Lakes. Many of the products are from federal agencies and are free to download. However, a number of the products are commercial and require payment. Table 3 presents a summary of the commercially available products in the Great Lakes for which costs have been identified.

In addition to the procurement of remotely sensed data, costs of translating that data into useful information must be considered. As part of the MARACOOS FY 2011 budget, $45,000 is allotted for acquisition and processing of satellite data.

2.5 GLIDERS

Gliders may be utilized to obtain more refined imagery than is available from satellite products. The MARACOOS FY2011 budget provides a per flight estimate of $50,000 and a glider purchase estimate of $150,000. These estimates will be refined with additional vendor information.

2.6 AUVS

Automated Underwater Vehicles (AUVs) may be used to collect deep-water observations and could support the collection of detailed bathymetric data. Costs will depend on the specific needs to be addressed by the AUV. Vendors will be used to estimate costs. C&C Technologies estimates the per-day cost of the operation of the HUGIN 3000 AUV at $55,000 for high-water deep-water mapping. OceanServer Technology offers an AUV for under $50,000. The YSI EcoMapper, used in Lake Michigan, varies in cost from $80,000 to $160,000, depending on the vehicle configuration.

2.7 DATA TRANSMISSION

The GLOS estimates in Table 1 demonstrate that data transmission costs are consistent and represent a small overall fraction of observing system costs. Data transmission costs will not be a significant driver in alternative evaluation.

2.8 ENTERPRISE MANAGEMENT AND MAINTENANCE ALTERNATIVES

Cost resources have been identified that will allow for comparison of four overarching management and maintenance strategies of the observatories: federal management through the NBDC, expansion of the existing ad-hoc systems, private party management, and a mix of those alternatives. The following is a bulleted list of the general resources that would be utilized to develop cost estimates for each management strategy:

- Federal management
  - NDBC cost estimates
- Expansion of academic ad hoc systems
  - Study team expertise (MTRI, UMD, and Clarkson)
  - Other current GLOS member estimates
  - Great Lakes Science vessels
  - Other IOOS members
- Private-party management
  - Sensor cost inventory
  - WeatherFlow
  - Fondriest
  - LimnoTech
  - Commercial shipping options
- Mix of alternatives
  - All of the previously noted resources

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3. DATA MANAGEMENT AND COMMUNICATION

Several approaches to Data Management and Communication (DMAC) will be evaluated as part of this investigation. The specific models of DMAC approach that will be evaluated are:

- Community Distributed
- Community Managed
- Community-Proprietary Hybrid
- Proprietary Managed

The team will use internal expertise, the experience of existing Great Lakes ad-hoc network of observing systems, and other IOOS organizations as resources to estimate costs of differing DMAC approaches. The costs of DMAC are driven by personnel expenditures.

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4. MODELING, ANALYSIS, AND DATA PRODUCT DEVELOPMENT

Modeling costs will be considered for both the development of new models and "operationalizing" existing models that could be used to provide users with data products. Modeling, analysis, and product development costs will be estimated using team expertise and the experience of other observing systems.

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LIST OF ACRONYMS

CZM – Coastal Zone Management
DIF – Directory Interchange Format (NASA GCMD)
DIF – Data Integration Framework (NOAA IOOS)
DMAC – Data Management and Communications
FGDC – Federal Geographic Data Committee
GCMD – Global Change Master Directory
GEOSS - Global Earth Observation System of Systems
GIS – Geographic Information System
GOOS – Global Ocean Observing System
GOS – Geospatial One Stop
IEOS – U.S. Integrated Earth Observation System
IOOS - Integrated Ocean Observing System
KML – Keyhole Markup Language
NASA – National Aeronautics and Space Administration
NMFS- National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
OGC – Open Geospatial Consortium
OOI - Ocean Observatories Initiative
OPeNDAP - Open-source Project for a Network Data Access Protocol
SOA – Service Oriented Architecture
THREDDS - Thematic Realtime Environmental Distributed Data Services
SDE – Spatial Database Engine
USGS- United States Geological Survey
XML – eXtensible Mark-up Language

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TABLES

Table 1. Cost estimates from current GLOS observation systems (GLOS, 2009)

Costs	**UWM Pioneer**	**UWM Endurance**	**UMD**	**UM**	**GLERL**
Standard Buoy	$18,000	$29,000	$32,400	$31,500	$42,000
Personnel	$25,000	$25,000	$4,800	$10,000	$40,000
Vessel	$5,000	$4,500	$6,500	$4,000	$30,000
Anchor			$2,100		
Cellular/Wi-Fi		$400	$400	$400	$400
Total	**$48,000**	**$58,900**	**$46,200**	**$45,900**	**$112,000**

Table 2. Summary of inventory of commercially available buoys and sensors

Item		Price Range	Comments
Buoys	TIDAS 9000	\$30,000-\$50,000+	Includes waves, weather, and current in base buoy
	MB-100	\$1,300-\$5,000+	Limited power availability - requires batteries
	NDBC-type	\$165,000-\$200,000	3-m discuss buoy
Sensors	Ammonium	\$400-\$600	
	Blue-green algae	\$1,900-\$2,500	Fluorescence
	Chlorophyll	\$1,900-\$2,500	Fluorescence
	Colored dissolved organic matter (CDOM)	\$2,200-\$2,700	Fluorescence
	Conductivity	\$250-\$450	
	Dissolved oxygen	\$350-\$600	
	Nitrate	\$300-\$600	
	PAR	\$800-\$2,000	
	Particle size distribution	\$30,000	Optical back-scatter LISST device
	pH	\$150-\$450	
	Water level	\$800-\$3,000	Wide range of products
	Water Temperature	\$200	Frequently included with sensors that measure other parameters

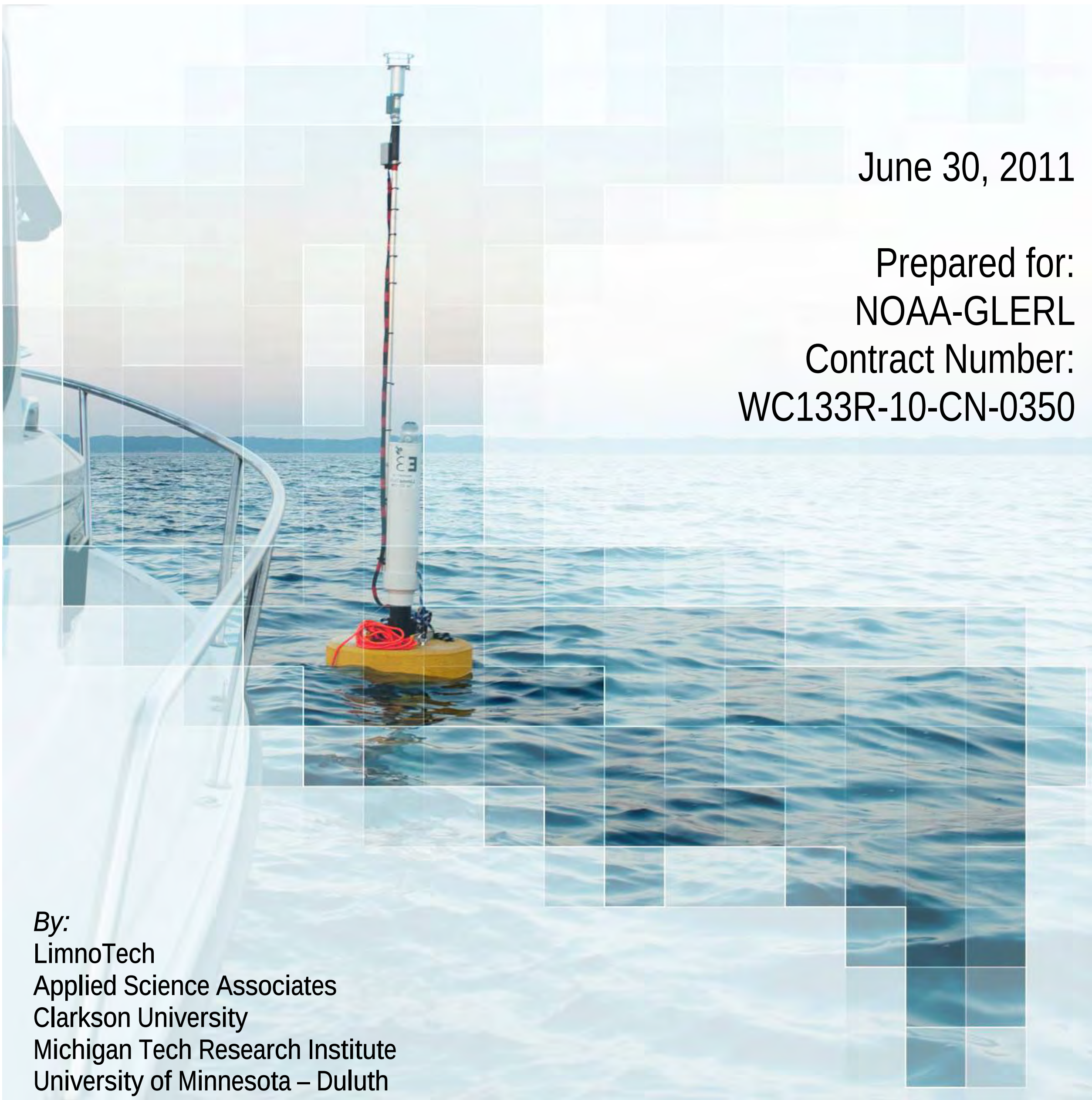
Table 3. Costs for remotely sensed products in the Great Lakes

Satellite System	Country	Launch Date	Sensor	Geophysical Quantities Observed	Pros	Cons	Cost	Availability
Terra (EOS AM-1)	USA/ Japan	1999 to present	ASTER	SST, CHL, DOC, SM, Turbidity, TSS, HABs, Ice Cover	Good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	USGS Earth Explorer, LPDAAC, GloVIS
			MISR					
Aqua (EOS PM-1)		2002 to present	MODIS					LPDAAC, MichganView.org, OceanColor.gsfc.nasa.gov, LPDAAC, MRTweb
OrbView-2	USA	1997 to 2005	SeaWiFS	Surface temperature, chl, doc, sm, turbidity, TSS, HABs, ice cover	Similar product to MODIS and when combined get coverage from 1997 to present; good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	OceanColor.gsfc.nasa.gov
OrbView-3	USA	2003 to present				No longer collecting imagery		GeoEye.com
ENVISAT-1	EU	2002	MERIS	SST, CHL, DOC, SM, Turbidity, TSS, HABs, Ice Cover	Good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds	None	OceanColor.gsfc.nasa.gov, http://envisat.esa.int/instruments/meris/
			ASAR					http://earth.esa.int/ dataproducts/
			AASTR	SST, wetland mapping, ice cover, surface winds, waves, oil spills	Resolution of < 0.5 K	Data availability requires ESA PI status		http://earth.esa.int/ dataproducts/
NOAA Polar Orbiting Platforms (POES) (numerous satellites)	USA	1978 (4 channel)	AVHRR	SST, cloud mapping, land-water boundaries, snow and ice detection	Long time history; good revisit time; synoptic coverage of all	Relatively coarse resolution; does not image through clouds		USGS Earth Explorer
Landsat-1/2/3/4/5/7	USA	1984 (L5)	ETM+	Turbidity, water depth, HABs, chl, doc, sm, bottom type and shoreline mapping	Long time history; fine resolution	Cloud dependent; revisit time every 16 days	None	USGS Earth Explorer, USGS GloVIS
		1999 (L7)						
Coriolis	USA	2003 to present	WindSat experimental passive microwave radiometer	Wind direction, surface temperature, soil moisture, rain rate, ice and snow characteristics, water vapor	Fully polarimetric; all weather synoptic; sensor will operate on NPOESS	Experimental satellite not operational	Free for approved research	(JPL PO DAAC) http://podaac.jpl.nasa.gov/ windsat/calval/data
QuikSCAT	USA	1999	SeaWinds scatterometer	Wind-speed measurements of 3 m/s to 20 m/s with 2 m/s accuracy; direction with 20 degrees accuracy; wind vector resolution of 25 km; ice cover	Daily synoptic maps; historical data back to 1999	Real-time scanning equipment failed in 2009; relatively coarse resolution	None	historical data from STAR, Center for Satellite Application and Research
ADEOS II	Japan/ USA	2002 (operational April 2003)	SeaWinds scatterometer	Wind-speed measurements of 3 m/s to 20 m/s with 2 m/s accuracy; direction with 20 degrees accuracy; Wind vector resolution of 50 km	Daily synoptic maps; historical data back to 1999	Satellite mission ended in 2003 with solar panel failure; relatively coarse resolution	None; Must register	National Snow and Ice Data Center (NSIDC) website

Satellite System	Country	Launch Date	Sensor	Geophysical Quantities Observed	Pros	Cons	Cost	Availability
Commercial Satellite Systems	USA	2001	QuickBird	Water depth, HABs, bottom features and shoreline mapping	Fine spatial resolution, revisit interval; optimize collection geometry for water penetration	Expensive; same issues as other optical sensors (i.e. cloud dependent)	$25/km² tasking; $13/km² archive	Digitalglobe.com; Minimum task size: 78 or 92 km²
		2007 to present	WorldView 1 & 2				$38/km² tasking	Digitalglobe.com; Minimum task size: 100 km²; Minimum archive order: 25 km²
		1999 to present	Ikonos				$20/km² tasking; $13/km² archive	Geoeye.com; Minimum task size: 100 km²
		2002 to present	SPOT 5	Vegetation, atmosphere, water optical properties	Two panchromatic bands combined for higher resolution; bands for atmospheric correction and water optical properties	Expensive; slightly lower resolution	Based on Order	SIRIUS (http://www.spotimage.fr)
Radarsat-1	Canada	1995-2008	SAR	Wetland mapping, ice cover, surface winds, waves, oil spills	All-weather day/night operation; high resolution	Images are not free	$3,600 - $8,400 per scene	http://gs.mdacorporation .com/
Radarsat-2		2007 to present						
ALOS	Japan	2006 to present	PALSAR	More complex wetland mapping, ice cover, surface winds, waves, oil spills	All-weather day/night operation; high resolution; fully polarimetric	Images are not free; revisit time is a function of polarization mode		Alaska Satellite Facility (ASF) DAAC
IRS-P6	EU	2004 to present	AWiFS					http://earth.esa.in/ dataproducts
TerraSAR-X	EU	2007 to present	SAR	Wetland mapping, ice cover, surface winds, waves, oil spills	Spotlight, strip mapping, and scanning; high geometric accuracy; will be joined by TanDEM-X twin satellite for 3D imaging	Images are not free	$2000 to $7000 per scene depending on resolution, tasked vs. archival (2008 prices); scenes are 5x10 km up to 100x150 km	(Online Archive) http://terrasar-x-archive.infoterra.de/

TECHNICAL MEMORANDUM 3: INVENTORY OF GREAT LAKES OBSERVATION SYSTEMS AND MONITORING PROGRAMS

Near-Term Design of the Great Lakes Observing System Enterprise Architecture



June 30, 2011

Prepared for:
NOAA-GLERL
Contract Number:
WC133R-10-CN-0350

By:
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1. INTRODUCTION

This memo is the third technical memorandum in a series of six that summarizes the current observations systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six tech memos cover the following topics:

1. Current state of data management in support of observing systems
2. Cost associated with observing systems
3. Inventory of Great Lakes observing systems and monitoring programs
4. Summary of Great Lakes DMAC infrastructure
5. Great Lakes models, scale, and operational status
6. Catalogue of Great Lakes user needs

Each of these tech memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

1.1 OBJECTIVE

The purpose of this technical memorandum is to document the observing systems and routine monitoring programs that currently operate within the Great Lakes Basin. The contents of this memo will be used to inform the development of the preliminary framework and conceptual design of the Great Lakes Observing System Enterprise Architecture.

1.2 SCOPE

As defined by GLOS, observing systems include sensors, stations, networks and field data collection are the primary means for gathering information on the chemical, biological and physical characteristics of the Great Lakes ecosystem. These observations are used in a host of monitoring programs to take the pulse of the Great Lakes, assess natural variability, drive ecosystem forecasting models, and assess the progress of restoration efforts.

This memo covers observation systems that fall into three major categories: real time in-situ, remote sensing, and discrete sampling. Real time in-situ systems include data collected by sensors attached to moored buoys, lighthouses, piers, land-based stations, and on vessels. These sensors operate on a seasonal to year round basis and include a range of telemetry options to transmit data to national data nodes. Remote sensing systems are dominated by satellite-based sensors, but also include land-based high frequency radar and in-situ measurements that are used to calibrate algorithms that convert raw data into a usable environmental product. The third category covers discrete sampling conducted as part of a routine monitoring program. For the purposes of this memo, only well established monitoring programs are included. We recognize there are many specialized/research oriented monitoring programs.

1.3 APPROACH

This memorandum is divided into the following three major sections: real-time in-situ observations, remote sensing, and monitoring programs. These three categories of observations cover the range of environmental monitoring that are currently operating in the Great Lakes region. For each category a broad overview is given of the major observation systems that are operated at the federal and state level as well as any programs operated by local governments or universities.

2. REAL-TIME IN-SITU OBSERVATION SYSTEMS

This section describes the major land and water based real-time in-situ observation systems that cover the Great Lakes basin. All of the systems listed in this section are comprised of a network of sensors that are connected to a data delivery system that is readily available to end users. While the frequency of data updates varies between programs, the update interval ranges from 6 minutes (NOAA water level) to hourly.

This section is broken down by sponsoring agency and also includes organizations whose system covers only a portion of the Great Lakes. Almost all of the data from the observation systems presented below is freely available to the public. However, some observation networks are private (Niagara River water level) or a collection of individual entities and not integrated into an organized delivery system (e.g. public and private water withdrawals/intakes). A list of the real-time stations is provided in Appendix A. Table A1 lists the buoy and shoreline based stations, while Table A2 shows major USGS gaging stations near tributary mouths. An overview map of the stations in Table A1 is provided in Figures D1 of Appendix D, while Figures D2 to D11 present a more detailed view of the real-time stations by lake.

2.1 NOAA

The federal agency with the largest observation system in the Great Lakes region is NOAA. NOAA's mission is to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs. The various components of NOAA that have assets in the Great Lakes Region are discussed in this section.

2.1.1 National Data Buoy Center (NDBC)

The National Data Buoy Center is part of NOAA and serves as the focal point for NOAA's buoy monitoring program. Programs under NDBC include the Coastal-Marine Automated Network (C-MAN), the Volunteer Observing Ship (VOS) program, and data collection from moored buoys. In addition to designing and deploying buoys, NDBC also serves as a data clearinghouse for data collected by buoys owned by other agencies and organizations. The purpose of NDBC is to collect monitoring data to support the National Weather Service (NWS) marine forecasts and provide helpful meteorological information to the public.

http://www.ndbc.noaa.gov/

2.1.1.a Moored Buoys

Many of the Great Lakes observing stations are moored buoys. Moored buoys are monitoring stations moored to a particular location that measure a suite of parameters that could include barometric pressure, wind, temperature, waves, and water quality parameters. There are a wide range of designs and purposes for moored buoys throughout the Great Lakes.

2.1.1.b Coastal-Marine Automated Network (C-MAN)

The Coastal-Marine Automated Network (C-MAN) was established by the NDBC and NWS in the 1980s and includes over 60 stations installed on lighthouses, capes and beaches, on nearshore islands, and on offshore platforms. The primary purpose of C-MAN stations is to collect meteorological data to support the NWS and public interest. Data from C-MAN stations is processed through the NDBC system. http://www.ndbc.noaa.gov/cman.php

2.1.2 Great Lakes Environmental Research Laboratory

The NOAA Great Lakes Environmental Research Laboratory (GLERL) administers two major observing programs on the Great Lakes. GLERL's Real-Time Meteorological Observation Network collects data at several stationary locations on Lakes Michigan, Lake Huron, and Lake Erie. Stations collect meteorological data including wind, temperature, and barometric pressure data that is provided to the NDBC in addition to availability directly from the GLERL website. GLERL also maintains webcams at five locations providing real-time images of several harbors on the Great Lakes. GLERL also operates the Real-time Environmental Coastal Observation Network (RECON). RECON stations measure a suite of water quality and physical parameters including dissolved oxygen and meteorological data from seabed to sea-surface. Real-time data is provided on the GLERL website for the public and is provided to a range of federal and academic programs. http://www.glerl.noaa.gov/res/recon/

2.1.3 Center for Operational Oceanographic Products and Services (CO-OPS)

The Center for Operational Oceanographic Products and Services (CO-OPS) is part of NOAA's National Ocean Service (NOS). The CO-OPS program collects water level and current data to support coastal physical oceanography, scientific research, and data to the public. http://tidesandcurrents.noaa.gov/

2.1.4 National Weather Service (NWS)

The NWS provides weather, hydrologic, climate forecasts, and warnings for the United States. Within the Great Lakes region they maintain many meteorological stations to provide real time data to weather forecasters and to improve model predictions. Many of the stations are based at airports, however some are located on the shoreline.

2.2 USGS

Within the Great Lakes Region the United States Geological Survey (USGS) maintains a large network of real time monitoring stations, water quality stations, and conducts a wide range of scientific research. Many of the USGS functions are divided on a state-wide basis; however the Great Lakes Science Center encompasses the entire basin. Listed below are several USGS monitoring programs that cover the Great Lakes basin.

2.2.1 National Water Information System (NWIS)

The USGS has collected water resources data at approximately 1.5 million sites in the United States and its territories. Data include surface and groundwater measurements of gage height (stage) and streamflow (discharge) collected at major rivers, lakes, and reservoirs. Groundwater data, including water level, are collected at wells and springs. Water quality data for both surface water and groundwater include temperature, specific conductance, pH, nutrients, pesticides, and volatile organic compounds. These parameters are measured at select stations.

USGS has been providing real-time and historic streamflow data on the Web since 1994. At that time, data for each state was available through separate web sites. The National Water Information System (NWIS) web system improved upon this by aggregating all the data into one national database accessible through one website. http://waterdata.usgs.gov/nwis

A selected subset of the NWIS stations are available in a sub daily format via the Instantaneous Data Archive (IDA). http://ida.water.usgs.gov/ida/

2.2.2 Near Real-Time Water Quality Data

At select USGS stations, where a water quality sonde is present, additional processing has been conducted to estimate pollutant loads and predict concentrations of other pollutants. Within the Great Lakes basin, only several sites in the Milwaukee area have been selected for incorporation into this program.

Continuous real-time water-quality data are used for decisions regarding drinking water treatment, regulatory programs, recreation, and public safety. Sensors in streams typically measure streamflow, water temperature, specific conductance, pH, dissolved oxygen and turbidity. Additionally, these measurements can be used as surrogates to compute real-time concentrations and loads of other water-quality constituents including phosphorus, pathogens, and suspended solids.

This National Real-Time Water Quality (NRTWQ) website (currently Iowa, Kansas, Maryland, Missouri, Nebraska, South Dakota, and Wisconsin) provides hourly computed concentrations and loads for sediment, nutrients, bacteria, and many additional constituents; uncertainty values and probabilities for exceeding drinking water or recreational criteria; frequency distribution curves; and all historical hourly in-stream sensor measurements. http://nrtwq.usgs.gov/

2.2.3 National Monitoring Network

The goal of the Network is to provide information about the health of our oceans and coastal ecosystems and inland influences on coastal waters for improved resource management. Currently there is a pilot program on Lake Michigan to increase the number of real-time sensors on major tributaries and to increase grab sampling at tributaries and nearshore areas.

Pilot Study Areas

Since 2007, Network concepts have been piloted and implemented in San Francisco Bay, Lake Michigan, and Delaware Estuary. Gap analyses and new monitoring have been funded by USGS, as well as through partnerships with local, state, regional, and federal organizations. The activities are coordinated with key organizations and IOOS regional associations, including the Delaware River Basin Commission; and Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA); Great Lakes Commission and Great Lakes Observing System (GLOS); and the San Francisco Estuary Institute and Central and Northern California Ocean Observing System (CenCOOS).

The Lake Michigan Pilot Study is also as an excellent surrogate for most coastal marine environments, with its focus on integrating observations of complex physical, chemical and biological processes and development of enhanced monitoring strategies. The Lake Michigan Pilot Study will ultimately generate a monitoring design that could be applied to the other four Great Lakes to better assess the ecological status of the entire Great Lakes basin, while complementary with monitoring parameters in other coastal regions of the United States through its cooperation in the National Monitoring Network for U.S. Coastal Waters and their tributaries. http://acwi.gov/monitoring/network/pilots/lmich/index.html

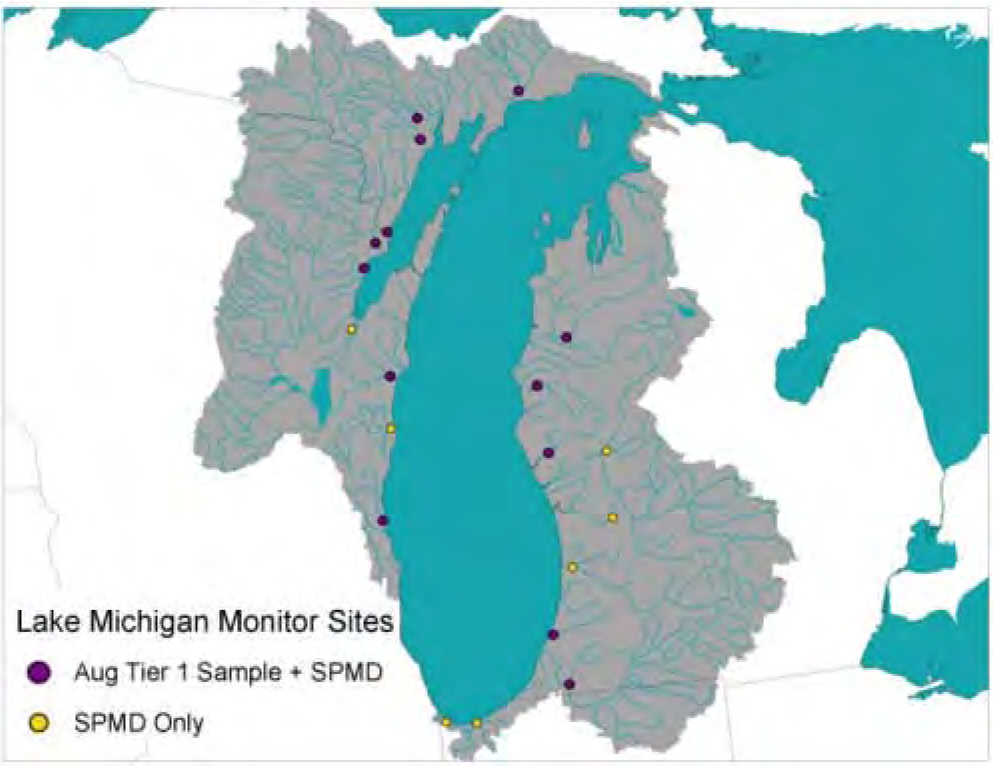

Figure 1. Location of USGS NMN intense water quality monitoring stations on major tributaries to Lake Michigan.

2.3 WATER SURVEY OF CANADA

The Water Survey of Canada is the national agency responsible for the collection, interpretation, and dissemination of standardized water resource data and information in Canada. All major water supply systems, hydro electrical generation facilities and irrigation projects in Canada have been designed, built, and operated using products and services of the Water Survey of Canada. The Water Survey of Canada provides real-time, current year and historical information for a network of over 2,200 sites in Canada and maintains and database containing historic data for over 5,300 non-active sites for the country. HYDAT is the archival database that contains all water information collected through the National Hydrometric Program. Data include daily and monthly mean flow, water level, and sediment concentration for over 2500 active and 550 discontinued hydrometric monitoring stations across Canada. The agency has incorporated microprocessor technology for data recording and storage with data collection platforms and land-line systems for real-time transmission.
http://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=4EED50F1- .

2.4 OTHER OBSERVATIONS

2.4.1 International Niagara Committee

The Niagara River Control Centre is located in the International Control Structure. The NRCC manages daily operations of the Niagara Joint Works Committee, maintains minimum flows over Niagara Falls, informs the Power Authority and Ontario Power Generation (OPG) of hourly diversion allowances, maintains records of water shares, and monitors water level gauges, weather, and ice conditions.

2.4.2 University of Michigan - MHL

The Marine Hydrodynamics Laboratories (MHL) is part of the Department of Naval Architecture and Marine Engineering at the University of Michigan, Ann Arbor. The mission of the MHL is to serve the marine community throughout the world through creating, communicating, preserving, and applying knowledge to shape the future of the marine environment.

The MHL's Upper Great Lakes Observing System began in 2005. With the support of partners, the local community, and the Great Lakes Observing System (GLOS), the MHL has added 4 more stations to date. Data types include wind direction, speed, and gust speed; air temperature; water temperature at surface and at varying depths; relative humidity; dew point; barometric pressure; solar radiation; as well as wave height, period, and direction.
http://uglos.engin.umich.edu/ .

2.4.3 Michigan Technological University

Michigan Technological University and the Michigan Tech Research Institute (MTRI) are implementing observing systems and modeling improvements that focus on needs of the Great Lakes region that affect the health, ecological integrity, and economic viability of the region.

The Lake Superior Water Monitoring and Information System connect scientific discoveries to public awareness of Great Lakes issues. Students and researchers will have the opportunity to work in a state-of-the-art laboratory developing, fabricating, and testing new aquatic and biota sampling instruments for studies and to train in collection of aquatic data as well as biological and sediment sampling.

Researchers utilize real-time satellite data, Michigan Tech's water and weather monitoring buoy observations, Ranger III instrumentation time-series data, and temperature sensor chains to generate data such as surface water temperature, wind speed, wave state, ice cover, chlorophyll, suspended matter, and dissolved organic carbon for Lake Superior. http://greatlakes.mtu.edu/ .

2.4.4 University of Minnesota – Duluth

The University of Minnesota, Duluth, with funding from the Great Lakes Observing System and the National Science Foundation, maintains a meteorological buoy roughly 10 miles northeast of Duluth, about a mile offshore of the McQuade Harbor.
http://www.d.umn.edu/~jaustin/buoy_2010/ .

2.4.5 University of Wisconsin – Milwaukee

The UWM Great Lakes WATER Institute is developing an underwater observatory designed for scientific studies of physical, chemical and biological processes in Lake Michigan and similar large lakes. GLUCOS, the Great Lakes Urban Coastal Observing System, is a buoy-based sensor network that will support research on the interactions between Milwaukee Harbor and the lake, and other processes in coastal Lake Michigan. The initial system configuration will consist of two large (Endurance) buoys designed to be deployed in fixed positions to gather long (up to 1 year) time series of data, and five smaller (Pioneer) buoys designed for rapid deployment over shorter periods of time (up to 2 months). The more transportable Pioneer buoys can be easily deployed in different array geometries to support changing scientific requirements in a single field season. The Pioneer buoy components of GLUCOS have been built and field tested, both individually and as a multi-buoy array in Lake Michigan near Milwaukee Harbor.
http://www.glwi.uwm.edu/research/aquatictech/GLUCOS/

2.4.6 U.S. Department of Transportation

Using federal grant funding, MDOT began installing a new system to monitor atmospheric and road surface conditions in an effort to better manage winter maintenance activities and to provide more travel information to motorists. They're part of the Michigan Department of Transportation's (MDOT) new Road Weather Information System, or RWIS. The concept isn't new (several other Midwestern states have similar systems), but the program is new to Michigan.

The system is made up of a network of Environmental Sensor Stations (ESSs). These stations combine several types of sensors to measure air and road surface temperatures, barometric pressure, wind, salt concentrations on the road surface, frost depth and dew point, as well as cameras to verify conditions at the site. Using the data collected from the 14 existing stations, MDOT and the contract county road commissions providing maintenance services can better predict when ice will begin to form on the roadway or bridge deck, or see when snow is blowing and drifting across the road. MDOT is working to provide motorists with an online view of the ESS cameras, which they could use to help make travel plans or decide when not to venture out. For now, the ESS data from Michigan and other states can be viewed at http://www.clarus-system.com/

2.4.7 St. Clair River/Lake Water Quality Alert System

The overall goal of this project is to protect drinking water from chemical releases and other threats to public health along the St. Clair River – Detroit River corridor. This corridor is the international waterway that runs between Canada and the State of Michigan and connects Lake Huron to Lake Erie.

The two main project tasks are: 1.) Installing, operating and maintaining water quality monitoring instrumentation at nine water treatment plants along the St. Clair River and Lake St. Clair; and 2.) Implementing a data management and communication system which will store and display the project monitoring data (on a real-time basis) and notify WTP operators when serious threats to water quality are present. Data is available online at http://www.rwqims.com/Home.aspx .

2.4.8 Army Corps of Engineers Wave Data

The Army Corps of Engineers Coastal and Hydraulics Laboratory collected wave data through 2005 at two locations on Lake Michigan. Hourly data on wave height, wave period, and wave direction were captured. The monitoring stations are no longer active.

2.4.9 Water Intakes

We realize there are other organizations that collect data that may or may not be readily available to the public. A good example is any facility that withdraws water directly from the Great Lakes, such as drinking water treatment plants and power generation facilities that utilize lake water for cooling. These facilities likely measure some parameters in real-time (e.g. temperature and turbidity) and may take periodic grab samples for parameters that can't be measured in real-time (e.g. solids, TOC, e.coli, etc.).

1. INTRODUCTION

This memo is the first technical memorandum in a series of six that summarizes the current observations systems and models, documents the costs associated with the observation systems, and catalogues the user needs of the Great Lakes community. The six tech memos cover the following topics::

1. Current state of data management in support of observing systems
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Each of these tech memos builds the knowledge base of the Great Lakes community by integrating information from multiple federal, state, and local organizations to better inform the development of an enterprise architecture for the Great Lakes Observing System.

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3. REMOTE SENSING

3.1 BACKGROUND

Remote sensing is the collection and measurement of spatial information about an object, area, or phenomenon at a distance from the data source being observed or measured, without direct contact (Aronoff 2005, Falkner 1995). Major types of remote sensing platforms include satellite-based sensors, aerial imaging, ship-based remote sensors, and ground based remote sensors (see the remote sensing platform tables below with more details). Remote sensing does not include emplaced sensors that are direct contact with the feature (such a buoy temperature monitor) whose characteristic is being measured, even if that data is then transmitted over a distance – those are "in situ" sensors, which can be particularly valuable in combination with remote sensing data. Remote sensing devices can be either active or passive, either emitting an active signal and then measuring information about the returning signal, or passive where reflected ambient visible and infrared wavelengths are collected after "bouncing" (reflecting) off an object. Both active and passive remote sensors take advantage of the electro-magnetic spectrum and the different wavelengths it consists of, including visisble light, near infrared, thermal infrared (collectively known as electro-optical or EO wavelengths), and microwaves (such as radar). Different remote sensing platforms tend to capture different parts of the spectrum in yielding information about the sensed feature, meaning that different needs can be filled by different sensors. Also critical to remote sensing is the concept of resolution, which can include spatial resolution, temporal, spectral, and radiometric resolution (see, for example, the NASA remote sensing tutorial by Nicholas Short, Sr. available at http://rst.gsfc.nasa.gov/Intro/Part2_5a.html and http://rst.gsfc.nasa.gov/) . Different remote sensing platforms have different resolution strengths, with the most common trade-off being between high spatial resolution and small area coverage; lower-resolution satellite platforms tend to cover larger areas on the ground with a single image.

3.2 SATELLITE PLATFORMS

Satellite sensing platforms are among the best known types of remote sensing devices. The "workhorse" platforms for Great Lakes remote sensing include Landsat, MODIS, the NOAA polar satellites (such as AVHRR), and the various commercial imaging satellites. Landsat has been collecting satellite imagery around the world since 1972, including in its current Thematic Mapper 30-meter spatial resolution form since 1982. This forms a desirable time-based series of earth and aquatic observations, with the same area on earth being collected approximately every 16 days and the data being distributed at no acquisition costs by the United States Geological Survey. The MODIS sensor (Moderate Resolution Imaging Spectroradiometer), present on two NASA satellites ("Aqua" and "Terra") provides twice-daily overpass for all locations in the Great Lakes (and elsewhere); however, its spatial resolution is relatively low, ranging from 250m to 1,000m depending on the spectral band used. Despite this moderate resolution, the large area covered by each image, the twice-daily overpass, and the 36 spectral bands it includes ranging from 620nm to 14.385 microns provide a wide range of analysis capabilities that are frequently being used to assess and monitor the region, especially the waters of the five Great Lakes and changes in land use around the region. The European MERIS sensor, on the ENVISAT-1 satellite, is a MODIS-like sensor with 3-day revisit and 300m spatial resolution that can complement and extend MODIS-based monitoring of Great Lakes ecology. For example, NOAA has started using MERIS as a workhorse for Great Lakes observations, including new projects such as monitoring harmful algal blooms.

The three commercial satellites most commonly used to map and assess the Great Lakes region are the DigitalGlobe Quickbird satellite (operational since October, 2001), GeoEye-1 (operational since September, 2008, that largely replaces the older IKONOS satellite from the same company), and DigitalGlobe WorldView-2 (operational since October, 2009). These offer up to 50cm resolution with panchromatic (grayscale) imagery and up to 1.65m resolution with multispectral imagery that includes near-infrared data, and up to daily overpasses depending on the satellite. However, the areas covered on the ground by a single image ("swath") are fairly small (around 20x20 km), and the imagery is expensive, especially for new dedicated collects for areas not already in the archive, with a cost of $3800 for a 10x10km minimum order area being representative.

Other satellite-based remote sensing platforms are also collecting important data for the Great Lakes. Radar-based active sensors have the advantage of being able to collect their observations in daytime or night-time, and are able to penetrate clouds so they can operate in more than just cloud-free days, unlike the above EO sensors. The Japanese ALOS PALSAR sensor, for example, is being used to improve mapping of wetlands and invasive species in the Great Lakes. The Canadian Radarsat satellites (versions -1 and -2) are being used to monitor ice cover and oil spills in various locations globally and also operate day and night and in all weather conditions due to being another radar-based satellite sensor. Other radar platforms also exist (see the satellite sensor table). An example of passive microwave sensors is the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) provides ice cover and wind speed estimates at 25km spatial resolution. A complete listing of orbiting satellites and their respective sensors, spatial resolution, and revisit time is shown in Table B1 of Appendix B.

3.3 OTHER PLATFORMS

Remote sensing observations can also be collected by shore and ship-based sensors. An example of shore-based remote sensors that have been at least experimentally deployed in the Great Lakes region include High Frequency (HF) Radar to measure information about currents, waves, wind, ships, and ice. Ship-based remote sensors include Very High Frequency (VHF) Radar, Doppler LiDAR, spectrometers, side scan sonars, and ultraviolet (UV) and infrared (IR) remote sensing devices. For example, ship-based spectrometers have been used to collect chlorophyll, dissolved organic carbon (DOC), suspended minerals, turbidity, total dissolved solids, and water temperature data. While potentially relatively inexpensive to measure these data, the data parameters are collected only along the ship track. A complete listing of shore and ship-based sensors is located in Table B2 and B3 of Appendix B.

Similarly, airborne-based remote sensing platforms are also capable of collecting critical Great Lakes data. Aerial photography from commercial vendors and Federal-based programs is being used at all scales of government to map properties, changes in land use, shoreline erosion, impervious surfaces, and many other features of interest to Great Lakes stakeholders. The US Army Corps of Engineers CHARTS system is mapping near-shore bathymetry and terrestrial topography along the entire Great Lake shoreline using LiDAR and multispectral sensors under an ongoing program, with data being distributed by the NOAA Digital Coast program. Multi-spectral and hyper-spectral platforms from private and government sources, such as the NASA AVIRIS sensor, the NASA Glenn Hyperspectral Imager, and the Argon ST Deadalus Airborne Mapping System have been deployed in the region. Commercial LiDAR vendors have created topography data for many Great Lakes states, cities, and counties, with the data proving useful for watershed modeling, shoreline changes, and other uses when it can be obtained at reasonable cost. A complete listing of shore and ship-based sensors is located in Table-B4 of Appendix B.

3.4 APPLICATION TO GREAT LAKES

Remote sensing is a critical component of monitoring the Great Lakes. It provides the capability for sensing across large areas, for a wide variety of variables, including when it is not possible to place in situ sensors in all locations. Remote sensing data can also complement and extend the value of in situ or other ground-truth data by using the in situ data to train and estimate values at other locations using satellite imagery. Imagery, or data derived from remote sensing, can also be used to provide information for models where other data are not available. Data access can be near-instantaneous; for example, with MODIS observations, the imagery is available the same day it is collected and it can quickly be turned into measurements of chlorophyll, sea surface temperature (SST), and ice cover for cloud-free locations. A listing of remote sensing resources in the Great Lakes is listed in Table B5 of Appendix B.

New remote sensing platforms are also coming online that will significantly enhance monitoring and measuring capabilities in the Great Lakes region. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) program has been planning multiple platforms in the 2011-2013 timeframe in a joint NASA, Department of Defense, and NOAA project. A NPOESS Preparatory Project satellite is due to be launched in 2011 that will include five sensors to measure these key variables: atmospheric and sea surface temperature, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties (see http://jointmission.gsfc.nasa.gov/) . Because of these factors, remote sensing is an integral component of the current and future architecture of the Great Lakes Observing System.

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4. MONITORING PROGRAMS

This section discusses ongoing monitoring programs from around the Great Lakes. The federal programs typically have coverage across all of the Great Lakes, while the state and local programs cover specific areas of the Great Lakes. A brief overview of the monitoring program is presented here. A listing of the USEPA, Environment Canada, and State of Michigan water quality stations is provided in Appendix C. A map of these stations is provided in Figure D12 of Appendix D.

4.1 FEDERAL

4.1.1 USEPA

4.1.1.a Open Lake Surveillance Program

The limnology program provides information on key environmental factors that influence the food chain and fish of the Great Lakes. The annual monitoring of the Great Lakes began in 1983 for Lakes Michigan, Huron, and Erie; in 1986 in Lake Ontario; and in 1992 for Lake Superior. The sampling strategy is to collect water and biota samples at specific water depths from a limited number of locations in each lake twice every year.
http://www.epa.gov/greatlakes/monitor.html

4.1.1.b Coordinated Science and Monitoring

The Coordinated Science and Monitoring (CSMI) process is a five year process that is comprised of two years of planning for an intensive field year in the third year of the process. Year 4 is reserved for laboratory analysis of samples acquired the previous year, and year 5 is for data analysis and reporting. The CSMI process is an ongoing cycle that builds on knowledge gained from previous efforts. Lake Michigan The table below shows a how the 5-year cycle plays out between 2010 and 2014. Each lake is abbreviated by its first initial.
http://cooperativescience.net/

Table 1. CSMI Cycle from 2010 to 2014.

CSMI Year	Description	2010	2011	2012	2013	2014
Year 1	Workshops/Meetings	H	O	E	M	S
Year 2	Detailed Planning	S	H	O	E	M
Year 3	Year of intense sampling	M	S	H	O	E
Year 4	Laboratory Analysis	E	M	S	H	O
Year 5	Reporting Phase	O	E	M	S	H

4.1.2 USGS

The USGS monitors water quality at select streams around the Great Lakes. Stations are monitored at regular and irregular intervals depending on the station. A listing of

4.1.2.a Routine WQ Monitoring

The USGS monitors various streams and rivers across the Great Lakes basin. A summary of these programs was not available, but data for specific stations can be downloaded through the NWIS system mentioned earlier. http://waterdata.usgs.gov/nwis/qw

4.1.2.b National Monitoring Network - Probabilistic

The probability-based survey of lake conditions will use 50 sites per lake with unequal weighting to include more points at shallow depths. The spatially-balanced probability design ensures strong regional coverage and representation throughout the lake, as can be seen in the figure below. Note that some sites are located in Canadian waters. This is necessary to understand the spatial continuity of conditions within the lakes shared by the US and Canada. It is expected that sampling at these sites will be closely coordinated with Canadian resource agencies and scientists. The probability design is complimented with a set of fixed, historical stations for continuity and analysis of temporal trends, which have generally been biased to the offshore zone, where some regular time series are now quite lengthy (decades). http://acwi.gov/monitoring/network/design/ .

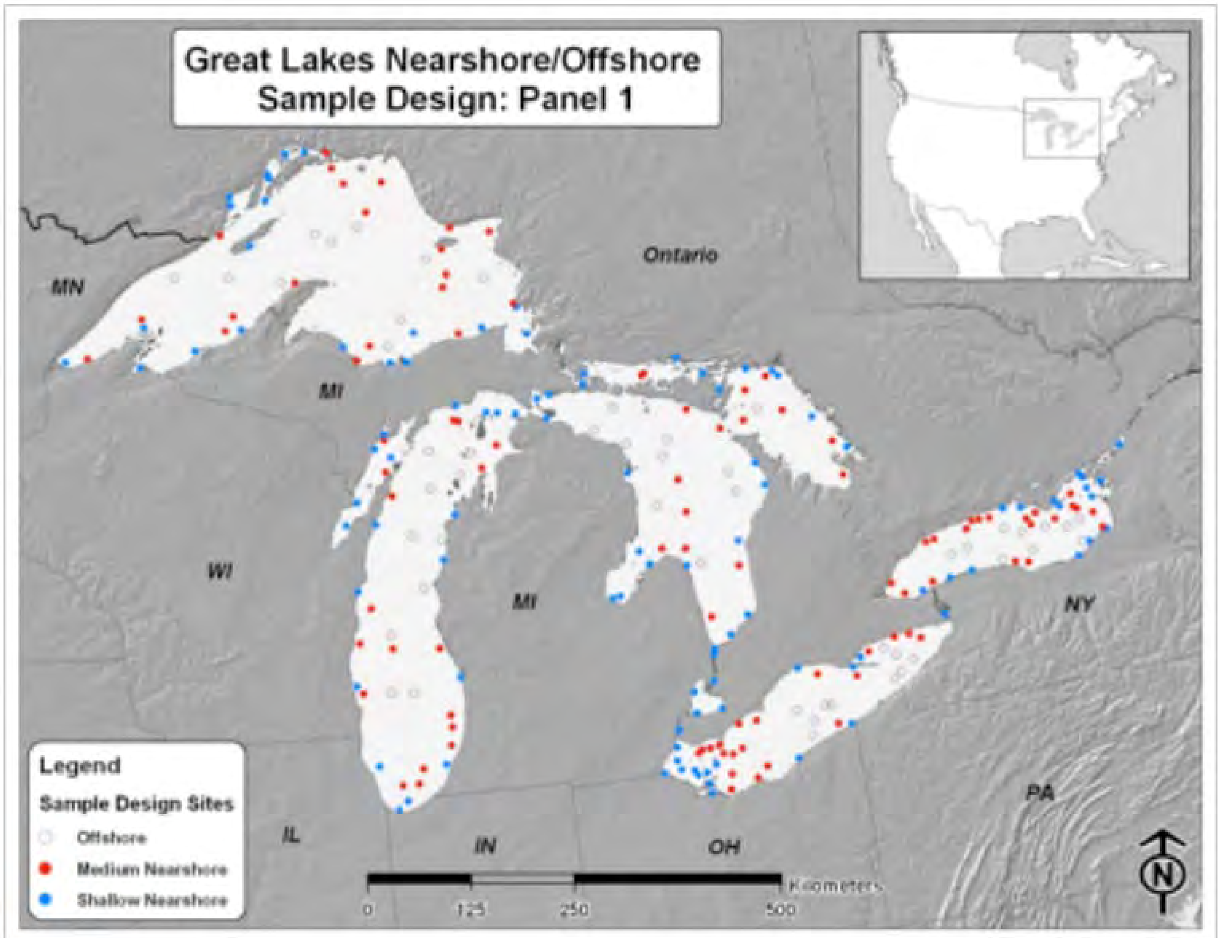

Figure 2. Location of USGS NMN porbabalistic sampling stations across the Great Lakes.

4.1.2.c Deep Water Science Project

The USGS Great Lakes Science Center (GLSC) has a long history of significant contributions to the understanding of aquatic resources in the Great Lakes, through partnerships and interactions with state, tribal, and U.S. and Canadian federal agencies. The GLSC conducts annual bottom trawl surveys in all five Great Lakes to assess the status of both predator and prey species, although much of our work is focused on prey fish populations. The prey fish assemblage, including alewife, gizzard shad, emerald shiner, rainbow smelt, bloater, sculpins, and lake herring is a vital trophic link in the aquatic ecosystem; prey fish populations may be limited both by their food supply and predators. In addition the USGS monitors abundance and health of top predator species such as lake trout and salmon and invertebrates, which are an important food source for prey fish. More information is available at http://www.glsc.usgs.gov/default.php .

4.1.3 Environment Canada

Environment Canada routinely monitors stations across the Great Lakes (except Lake Michigan). Their monitoring program tends to visit more stations than USEPA-GLNPO, but the frequency is only once per year or every other year depending the parameter and lake.

4.1.4 National Atmospheric Deposition Program

The program is a cooperative effort between many different groups, including federal, state, tribal and local governmental agencies, educational institutions, private companies, and non-governmental agencies. There are many precipitation monitoring stations within the Great Lakes region that are part of the National Trends Network (NTN), Mercury Deposition Network (MDN), or the Atmospheric Integrated Research Monitoring Network (AIRMoN). http://nadp.sws.uiuc.edu/NADP/ .

4.1.5 NOAA – GLERL

4.1.5.a Long Term Trends in Benthic Populations

GLERL performs continuous sampling of benthic populations in Lake Michigan in order to monitor the relative health of the lake. This program has been ongoing since 1980. Recently, Dreissena (zebra and quagga mussel) population data has been specifically targeted.

4.1.5.b Long Term Trends in Pelagic Populations

This program monitors the pelagic food web in Lake Michigan in areas with comparative historical data available. The purpose is to expand understanding of the pelagic food web, leading to a better understanding of its impact on fisheries and lake ecology.

4.1.6 Integrated Atmospheric Deposition Network

The Integrated Atmospheric Deposition Network (IADN), funded by the USEPA and Environment Canada, maintains a series of stations around the Great Lakes to measure the atmospheric load and trends of priority pollutants to the Great Lakes. The program is tasked with acquiring quality-assured air and precipitation concentration measurements, with attention to continuity and consistency of those measurements, so that trend data are not biases by changes in network operations or personnel. In addition the program should try to determine the sources of the continuing inputs of those chemicals. There is currently one master station per Great Lake along with several satellite stations.
http://www.epa.gov/greatlakes/monitoring/air2/iadn/resources.html .

4.2 STATE AND LOCAL

Most of the large-scale observation networks on the Great Lakes are established as federal government or university programs. The states bordering the Great Lakes have varied involvement in monitoring and observation systems. In general, states perform monitoring and observation activities to gather information on bacteria for potential beach closures and water quality data for 305(b) reporting under the Clean Water Act.

For areas that are identified as thick observation areas, these programs should be evaluated for possible inclusion in an observation network design. The following are descriptions of some specific state programs for monitoring and observation that are being performed in addition to federal, academic, and routine monitoring.

4.2.1 Michigan Department of Natural Resources and Environment (MDNRE)

The Michigan Department of Natural Resources and Environment (MDNRE) conducts monitoring on the Great Lakes and within the Great Lakes watershed to support state initiatives. MDNRE does not duplicate monitoring efforts already being conducted. MDNRE participates in the Lakewide Management Plan (LaMP) program monitoring pollutants at locations throughout the state. There are several programs under which MDNRE conducts monitoring and observation.

4.2.1.a Saginaw and Grand Traverse Bay

The Saginaw Bay Coastline Initiative is a comprehensive initiative to evaluate the economic and ecological development of the Saginaw Bay region and includes monitoring pollutant reductions such as phosphorus. The MDRE collects samples monthly on Saginaw Bay and seasonally on Grand Traverse Bay.

4.2.1.b Tributaries (including Connecting Channels)

The WCMP is an important component of the statewide surface water quality monitoring activities outlined in the January 1997 report prepared by the MDEQ, WB, and the MDEQ, Land and Water Management Division, entitled, "A Strategic Environmental Quality Monitoring Program for Michigan's Surface Waters" (Strategy). The WCMP incorporates the goals of the Strategy, which are:

1. Assess the current status and condition of individual waters of the state and determine whether standards are being met.
2. Measure temporal and spatial trends in the quality of Michigan's surface waters.
3. Provide data to support MDEQ water quality programs and evaluate their effectiveness.
4. Detect new and emerging water quality problems.

4.2.2 Illinois Environmental Protection Agency (IEPA)

The Illinois Environmental Protection Agency (IEPA) and the City of Chicago have been collecting monitoring data on Lake Michigan since the 1930s. In 2010 IEPA began monitoring Lake Michigan more frequently under the Lake Michigan Monitoring Program (LMMP). This program focuses on monitoring water in the near shore area, harbors, and near public water supply intakes for a wide range of physical and chemical parameters including temperature, DO, pH, nutrients, TSS, and metals, among others. Sites are monitored on a rotating basis.

In addition to the LMMP program, IEPA conducts fish contaminant monitoring in Lake Michigan on an annual basis. IEPA participates in the Lakewide Management Plan (LaMP) program monitoring pollutants at locations throughout the Great Lakes tributaries of Illinois.

4.2.3 Indiana Department of Environmental Management (IDEM)

IDEM monitors water quality in Lake Michigan for bacteria regularly to inform beach closure and public health decisions. IDEM participates in the Lakewide Management Plan (LaMP) program monitoring pollutants at locations throughout the Great Lakes area of Indiana.