Predicting Bacteria Concentrations On The Nation's Beaches

Walter Frick, Ph.D., Marirosa Molina, Ph.D
OfficeofResearchandDevelopment, NationalExposure ResearchLaboratory, EcosystemsResearch Division,Athens, Georgia

Year of Water: Thirty Years of Progress Through Partnering

EnvironmentalIssue

Withthepossibleexceptionofthosewhovaluesolitudeaboveallelse,noonewants beachesclosedasaresultofhighbacterialwaterconcentrations.Although microbiologyisconstantlymakingnewbreakthroughsinmicrobialdetectionand identification,beachclosuredecisionsstillfrequentlyrelyontime-intensivetestsfor indicatorbacteriawhichdonotdifferentiatebetweensewageplumesfromdistant sourcesreachingabeachandthevisitofflocksofseagullstothebeachthe previousday.Currentprocedureallowsonlyforafter-the-factreactionstohigh bacterialcounts,costingmunicipalitiesuntolddollarsinlostrevenuesand remediationactions.

Approach

ERDscientistsaredevelopingmodelsthatwillintimebeabletoaccuratelytrackthe movementofwaterandsourcesontothenation'sbeaches.Models,liketheERD VisualPlumesmodel,willbemodifiedtotrackbothpointsources(likesewage treatmentplants)andnon-pointsources(likebirdsonbeaches).Anotheraspectof thisresearchseekstodevelopandimprovebacterialsubmodelsthatwillbespecific toactualpathogens,ratherthanindicators.Toadvance,pathogensmustbe positivelyidentifiedandmodeled.MicrobialSourceTracking(MST)isatechniquefor quantifyingpathogens.ERDResearchersaredevelopingafastandreproducible alternativeDNA-basedMSTmethodologytoitemizecomplexsourcemixtures. Thisworkenvisionsamodel,workingtitle"VisualBeach",thatwillusereal-timedata andadvancedbiologicalinputs,forexample,MicrobialSourceTracking(MST),GIS data(bathymetry),forecastdata,particularlyweatherdata,and,incoastalareas, astronomicaltidefactors.

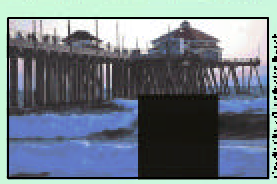
Impact

Microbialcontaminationleadstobeachclosureandposesthreatstohumanhealth. Thepurposeofthisworkistohelpprotectaquaticecologicalsystemsand recreationalresources.Ifsuccessful,themodelwillhelpdeviseeffectivesource controlstrategiesandhelpdifferentiatebetweendangerousepisodes,requiring closure,andbenignonesnotrequiringdrasticmeasures.Itwouldenablehealth officialstodiscriminatebetweendangerousandbenignexposurelevelsandhelp treatmentplantoperatorsdevelopstrategiestopreventmostbeachclosuresdueto importantpointsources.

NationalScope

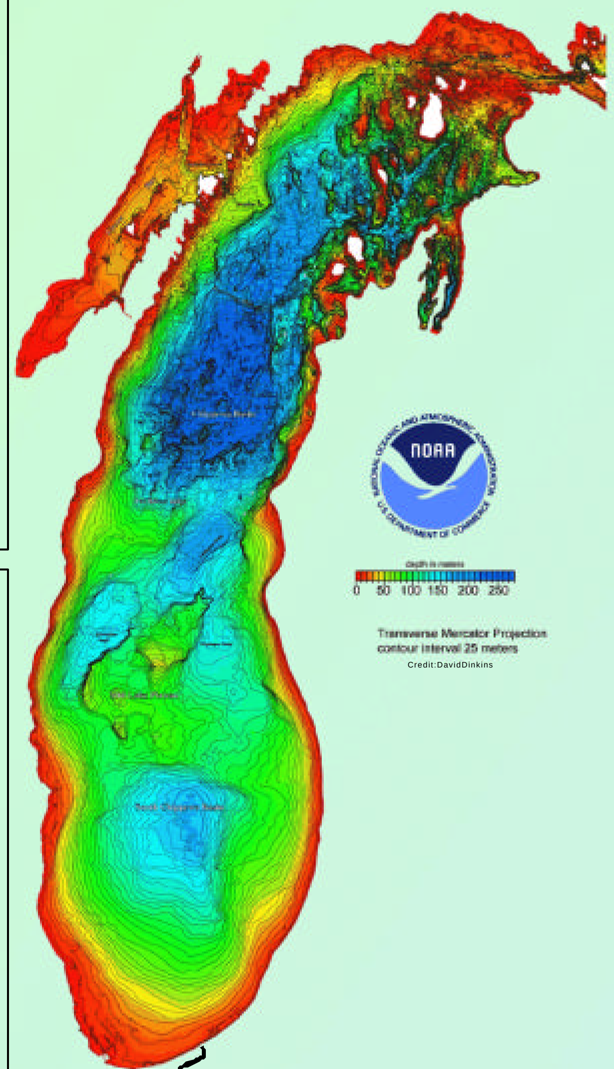
Anexampleofanationalproblem,HuntingtonBeach,Californiawasclosedin1999 duetoelevatedbacterialcounts.VisualPlumeshasbeensuccessfullytestedonthis problem

July-August1999BeachClosureMaplocatestheclosedbeach(greenstripe)and themajorOrangeCounty4-milelongsewageoutfalldischargingat60mdepth. Insetsshowbeachsceneandtreatmentplant.



FutureStudySite

LakeMichiganBathymetry



depth in meters
0 50 100 150 200 250
Transverse Mercator Projection
contour interval 25 meters
Credit:DavidDinkins

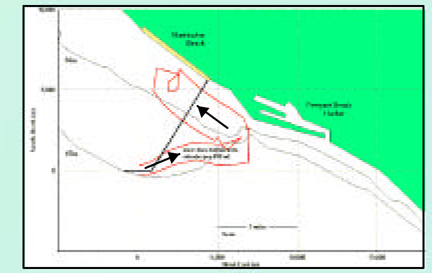
Values,Resources,andProblems

IndianaDunesNationalSeashore

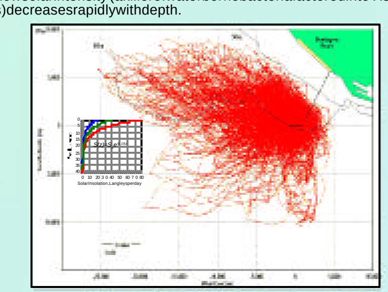
Themodeldescribedherewillbetestedon WestBeach(IndianaDunesNationalSeashore,LakeMichigan)datathissummer.

Modeling

AVisualPlumessimulation. Areleaseofsewageformingaplume(redoutline) trackedfor36hours(plumeelementismovedin2-hrincrements)andforminga plumethatencroachesHuntingtonBeachinwinter2001,ararevent.

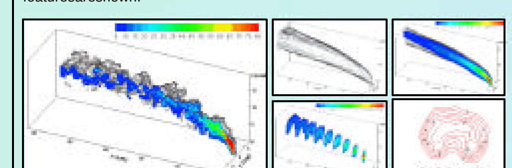


Notspaghetti,amonth-longVisualPlumessimulation. June-July2000 simulationsshowareasreachedbysimilarlycontaminatedplumesduringthat period.Note,thesourcedidnotimpactthebeachduringthattime.Insetdiagram showsshowsolarintensity (akillerofwaterbornebacteriafactoredintoVisual Plumes)decreasesrapidlywithdepth.



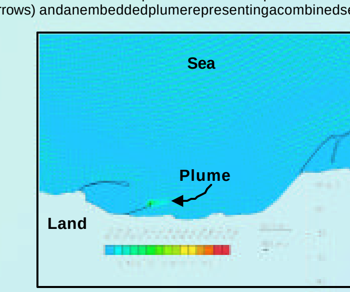
HydrodynamicsandPCR

Thebeachbacteriamodelingspanstwomaindisciplines,hydrodynamicsand microbiology.Shownhereisalaboratoryplumeimageproducedthroughlaser-inducedfluorescenceimaging.Bothsurfacefeaturesandfalsecolorcross-sectional featuresareshown.



Towingchannelplume,laser-inducedfluorescenceimagery

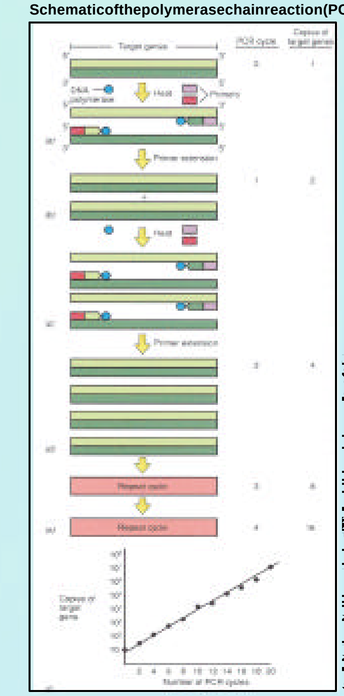
PlansfortheLakeMichiganModel Thenextgenerationofbeachbacteriamodels willincludedensecurrentinformationbasedonfinite-elementhydrodynamical modelsthatwillmakeforecastspossible.Thisexampleshowsacurrentfield (light greenarrows) andanembeddedplumerepresentingacombinedseweroverflow.



PolymeraseChainReaction(PCR)

PCRisamethodbywhichverylowconcentrationsofDNAareamplifiedtoimprove detectionoftargetorganisms.However,conventionalPCRmethodscannotbe usedtodeterminebacterialnumbers.Recently,researchershavedevelopedan alternativePCRmethodcommonlyknownasreal-timePCR,wherethenumberof amplicons(amplifiedDNAproducts)fromeachreactioncyclearemeasured. Productaccumulationisquantifiedduringtheexponentialphaseoftheamplification process.Theprocedurecanbeusedwith16S-rDNAprimersspecifictoagroupor speciesoffecalindicatorbacteria.Thisapplicationwillallowaccuratemonitoring andquantificationofspecificfecalindicatorbacteriainrecreationalwatersandmay reducedetectiontimeto3hours.Theschematicdiagramshowsprinciplesofthe applicationofpolymerasechainreactiontechnology.

Schematicofthepolymerasechainreaction(PCR)



Conclusion

TheVisualBeachmodelingapproachattemptstoprovideaholisticconceptualand numericalmodelofbacteriatransportandfate.Itattemptstorealisticallymodelthe mostimportanttransportandfatemechanisms.Itanswersquestionslike:Wheredid thewatercomefrom?Whatweretheconcentrationsofbacteriainitially?Towhat stressorswerethebacteriaexposedduringtheirtransitfromsourcetoreceptor regions?Andsoon.Thebasicphilosophyisthatincreasinglybettermodelswillhelp betterunderstandandmodelbacteriatransportandfateandultimatelyhelpreduce beachclosures.

Acknowledgement: ThecommentsandsuggestionsofCandidaWestaregratefullyacknowledged.

Partnering to Protect Human Health and the Environment