

## **DEVELOPMENT OF A GIS INTERFACE FOR WEPP MODEL APPLICATION TO GREAT LAKES FORESTED WATERSHEDS**

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# DEVELOPMENT OF A GIS INTERFACE FOR WEPP MODEL APPLICATION TO GREAT LAKES FORESTED WATERSHEDS

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## ABSTRACT

This presentation will highlight efforts on development of a new online WEPP GIS interface, targeted toward application in forested regions bordering the Great Lakes. The key components and algorithms of the online GIS system will be outlined. The general procedures used to provide input to the WEPP model and to display model output will be demonstrated.

The Water Erosion Prediction Project (WEPP) model is a computer program for soil erosion estimation, used at the scales of hillslopes to small watersheds. The program, written in FORTRAN, accepts text input files and writes output to text files allowing a general or specialized user interface to be created with other software. On the desktop the WEPP Windows interface is the primary software used to create WEPP input files and to display results. The WEPP Windows interface is written in Microsoft Visual C++ and is comprised of a front-end GUI that contains all the Windows specific code and a back-end module in C++ capable of running on other operating systems. In addition to the WEPP Windows interface other user interfaces for WEPP have been developed over the years. These include ArcGIS-based GeoWEPP, which can set up WEPP watershed simulations on a desktop, US Forest Service web-based WEPP interfaces customized for disturbed areas and forest roads, a general ARS web-based interface for hillslopes, and an online GIS interface for small watersheds.

The newest online GIS WEPP interface uses the OpenLayers and MapServer GIS software with base image data from Google. Server web pages are written using a combination of PHP and HTML, which connect to a server PostgreSQL database. In addition, custom programs written in C++ assist in preparing WEPP inputs and interpreting WEPP outputs. A user needs only a web browser to set up and run a WEPP online GIS simulation, as all data and programs reside on web servers. GIS data sources include USGS 30-m National Elevation Data, USGS topographical maps, USGS land cover and NRCS soil data. Daily climate inputs are generated from the long-term climate parameters of the nearest weather station using CLIGEN. Monthly climate parameters can be adjusted by using the PRISM gridded data to account for locations away from CLIGEN stations. The online GIS WEPP soil data for an area of interest can be retrieved using the NRCS Soil Data Access web services, which provide a way to query the NRCS soil database and return spatial data and tabular soil parameters. General USGS land use classes are associated with detailed WEPP management inputs, which the user can adjust. Other GIS layers can be added to the map for reference.

Interface components specific for forest applications of WEPP have been added to the new online GIS interface. These include the ability to adjust the default land use or soil data for a subcatchment to represent conditions after a forest fire or timber harvest. Soil properties can also be customized to represent disturbed forest conditions. In addition, hydraulic measures (e.g., impoundments) can be added for a more detailed assessment. Simulation projects developed online can be downloaded and run using the WEPP Windows interface, which provides the user the ability to further customize the WEPP inputs.

**KEYWORDS.** Geographic information systems, Internet, Interface, Soil erosion, Prediction, WEPP.

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## INTRODUCTION

Application of complex environmental models requires users to spend considerable time assembling the necessary model inputs. In addition, if the model is based on GIS analysis it also requires the user to be proficient with GIS software to preprocess model inputs into the required formats. Models that can be run from Internet servers allow use of a common web browser as the interface. The data and model are stored on the server so nothing is required to be downloaded by the user. WEPP has been ported to web servers to run hillslope model simulations. The USDA Forest Service has a suite of applications (Elliot, 2004) and the National Soil Erosion Research Laboratory (NSERL) has general web based interfaces for quick hillslope erosion and runoff estimates. A web based watershed interface for WEPP was developed using the MapServer online GIS, USGS 30-m DEM data and USGS 1992 Landcover, see Flanagan et al. (2004a,b). The online GIS interface used algorithms developed for the desktop GeoWEPP (Cochrane and Flanagan, 1999; Renschler et al., 2002).

The Great Lakes Online WEPP interface, available at <http://134.121.202.207/gl>, extends the previous WEPP online GIS application to include real-time access to NRCS SSURGO soil spatial data which is translated into WEPP soil inputs. The OpenLayers mapping interface is used as a front end to MapServer allowing access to Google Maps based images as background layers. To meet the needs of WEPP users, forest specific soils and landuses were included along with some capability to change the watershed simulation scenarios.

## SOFTWARE ARCHITECTURE

The Great Lakes WEPP web main user interface is written in PHP, HTML and JavaScript. The OpenLayers software is an open-source Javascript package that allows image layers to be displayed in geo-referenced space (OSGeo, 2010b). It supports connections to GIS servers using Web Mapping Services (WMS) (OGC, 2006), as well as Google Maps and other image servers. OpenLayers is not a full featured GIS. It primarily handles images and overlays them providing the user with the ability to display layers. For GIS functionality the open-source MapServer software (OSGeo, 2009) is used to convert GIS data into images and reproject data layers to be compatible with the Google image base layer. Other programs are invoked from PHP to prepare data for input to the models and add data to the MapServer configuration which can then be displayed to the user through OpenLayers (Figure 1).

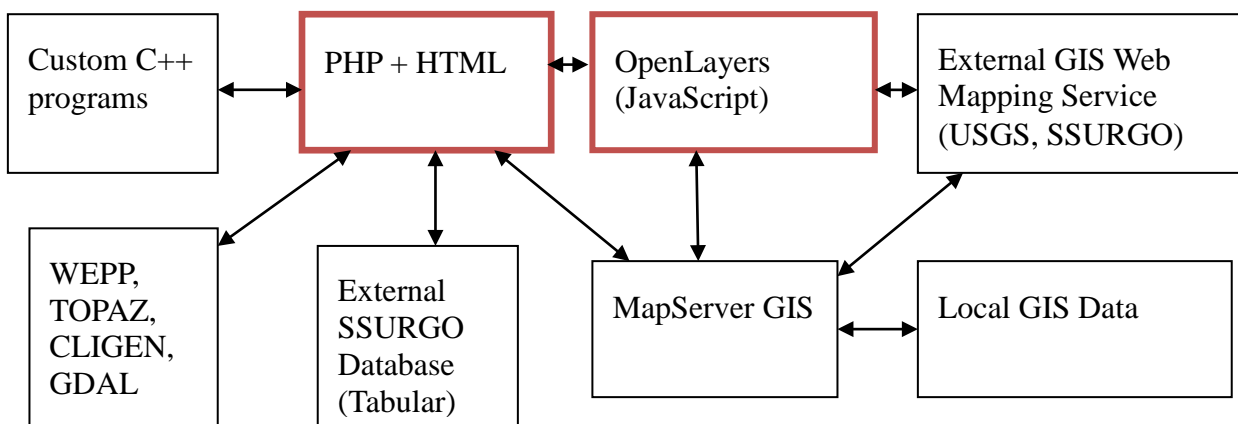


Figure 1. Major software components in the WEPP GIS Internet interface. The PHP, HTML and OpenLayers software control how the content is displayed.

The server PHP and OpenLayers code provides the central point of control in setting up and running the WEPP watershed simulations. WEPP model soil input data are prepared by querying the NRCS SSURGO database remotely. Soil polygon map units are displayed, as well as the detailed soil properties that are used to create WEPP soil input files. Part of the custom C++ programs listed above translate all data into WEPP format input files as described in Flanagan and Livingston (1995).

## DEFINING THE WATERSHED

The first step in setting up a WEPP watershed simulation is to define an area of interest. This is done by zooming into an area on the screen. The extent of the visible window defines the DEM area that will be analyzed. The OpenLayers interface requests the appropriate image tiles from the Google map service and displays them. The DEM for only the area of interest is extracted from the larger National USGS 30-m Elevation DEM (Gesch et al., 2002; Gesch, 2007). Using programs from the Geospatial Data Abstraction Library (GDAL) (OSGeo, 2010a), the extracted section of the DEM is reprojected to UTM coordinates, and this produces a grid where all the cells are square.

To define the channel network, the DEM file is passed to the TOPAZ program (Garbrecht and Martz, 1997). The output from TOPAZ is an ASCII grid file that defines the cells where channels are found. This grid file is added to the MapServer configuration and to the OpenLayers interface. All layers must be reprojected to match the Google Maps base layer, which is Web Mercator projection. The reprojection from UTM is handled in MapServer so that OpenLayers always has image tiles in the same projection.

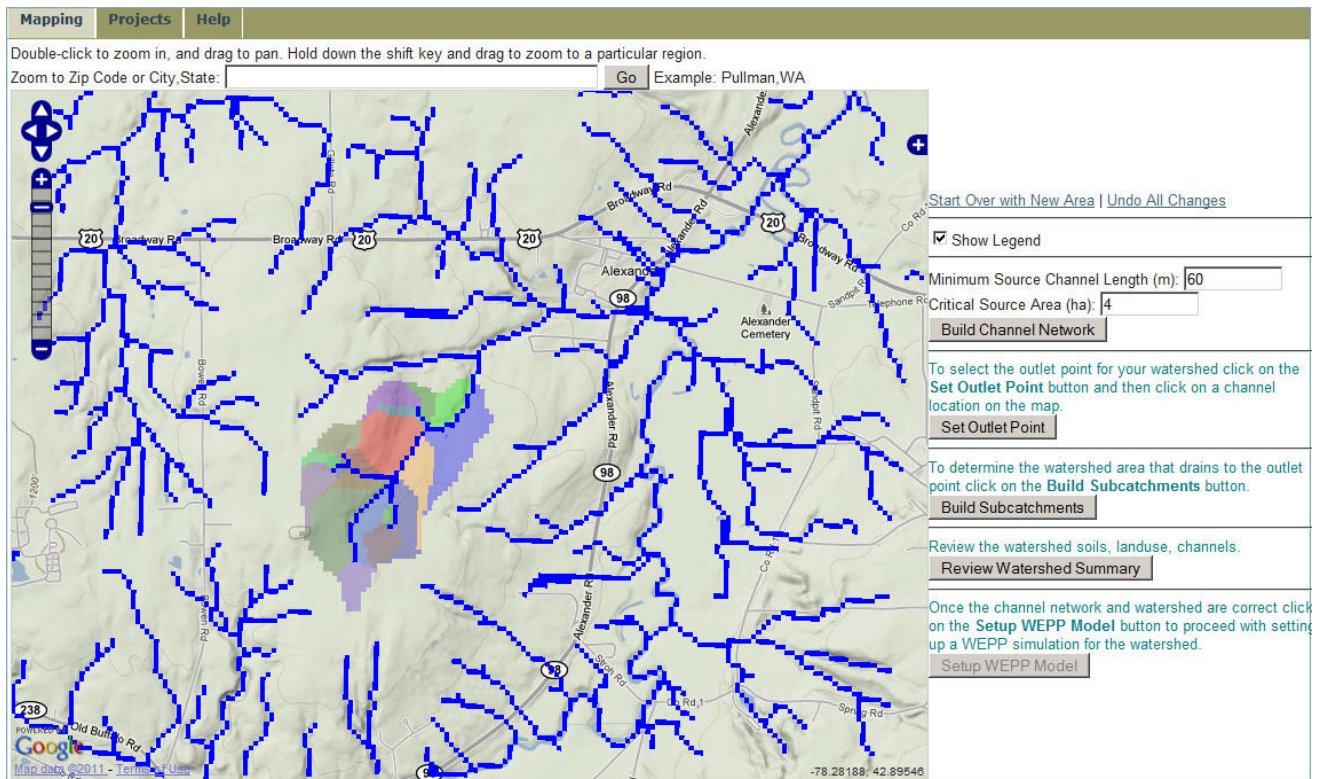
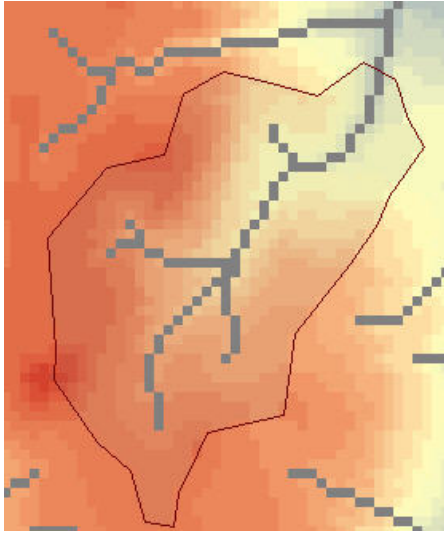
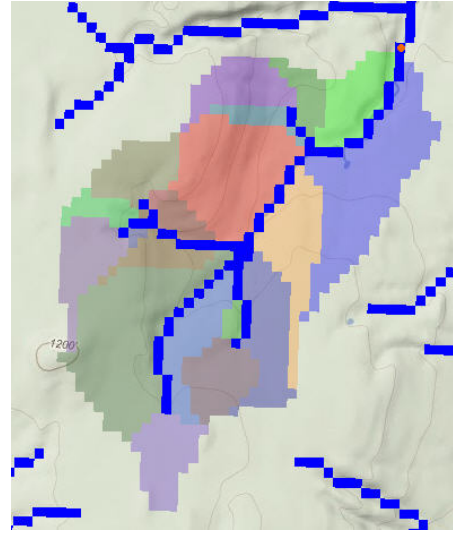


Figure 2. Main WEPP GIS Internet page showing channels and subcatchments over a Google Maps base layer. The outlined watershed is the area WEPP will use in the simulation.

After a channel network is displayed, the user selects a watershed outlet point which lies on a channel cell. With the outlet cell defined, TOPAZ is run again defining the watershed and subcatchment boundaries (Figures 3, 4). This TOPAZ output contains additional grid files that define flow vectors and channel information indicating what subcatchments drain to which channels.



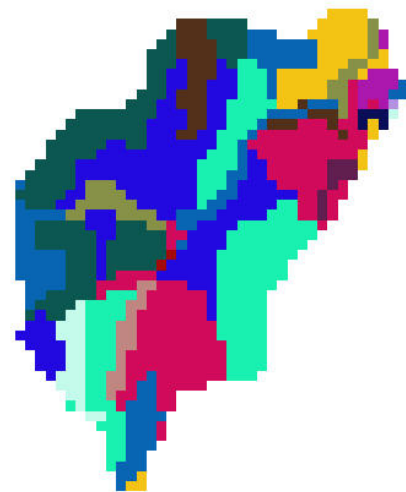
**Figure 3. DEM Grid with watershed boundary determined after selecting a watershed outlet at the upper right.**



**Figure 4. Subcatchment grid, each area will be modeled as a WEPP representative hillslope.**



**Figure 5. Landuse grid, darker brown areas are cultivated crops, lighted green are forest.**



**Figure 6. Soils grid, derived from SSURGO after polygons are translated into a raster.**

Using the same area of interest as the watershed boundary, the PHP code uses the GDAL library to extract a matching section from the USGS 2006 National Land Cover grid (Homer et al., 2004) and reproject it into the corresponding UTM zone. The land use grid is stored as an ASCII grid file (Figure 5). To facilitate linkage to WEPP input files, a translation file is established between the USGS identifiers in the land use grid file and the WEPP management input files.

The SSURGO soils data is used as the input for running the WEPP simulations. Access to the SSURGO data is provided by a set of web services made available by NRCS (NRCS, 2011). To reduce the number of query requests to the SSURGO server, the area of interest is only the watershed boundary. The first request to the NRCS server obtains the map units in the area. The data are returned in the form of polygon vertices. To more easily work with the data the polygons are converted into a grid file using the GDAL programs on the server. The resulting grid aligns with the extracted DEM and land use grids (Figure 6). The next set of requests obtain the detail soil properties and layer information. As the soil data are assembled for each map unit a WEPP format soil file is created with the same id number. The SSURGO polygons displayed to the user come from a separate request using WMS that returns map unit polygons as images that are overlaid on the map.

Some forested areas do not have SSURGO data defined. In these cases the soil grid is defined by a user-selected soil installed locally on the web server. These soils include those from the basic WEPP install and also specialized forest files customized for fire and other disturbances.

## CUSTOMIZING THE SIMULATION

The DEM, land use, and soils grids along with the climate location provide a starting point for conducting a WEPP simulation. Changes to the default configuration may be needed if the known conditions are different than what was established or the user wants to explore alternate scenarios.

### Changing the land use or soil for an area

Land use is changed from the user interface by selecting a subcatchment area and picking a new WEPP management scenario. The land use grid is modified to link with the new management. The soil for a subcatchment may be changed in a similar manner.

### Creating a new land use or soil

A management scenario can be customized by specifying an initial ground cover percentage. The new management is given a new name that is unique to the user session. A soil can be customized by adding a restricting layer. General editing of the management and soil inputs are not permitted at this time.

### Adding a Buffer

A buffer can be applied to a subcatchment by specifying the buffer management and length of the buffer. The length does not have to be a multiple of the grid cell size. In the case of buffers, the land use grid is not modified; a command is inserted into the simulation control file so that when the WEPP runs are made for the subcatchment an overland flow element (OFE) break is inserted and the buffer management applied to the last section of the hillslope for the specified length. The buffer management will override the land use grid.

### Adding an Impoundment

Impoundments, such as filter fences and sediment basins can be added at the end of channel segments. The user clicks on a channel and then selects the impoundment type to add. WEPP allows impoundments to be placed in other areas of a watershed but this GIS interface restricts the placement to channel segments. The WEPP watershed project file channel network specification is updated to reflect any impoundments added.

### Applying PRISM Adjustments

The CLIGEN (Nicks and Gander, 1994) database of 2600+ stations is used to determine the one closest to the watershed outlet. The climate data generated from CLIGEN is daily simulated parameters based

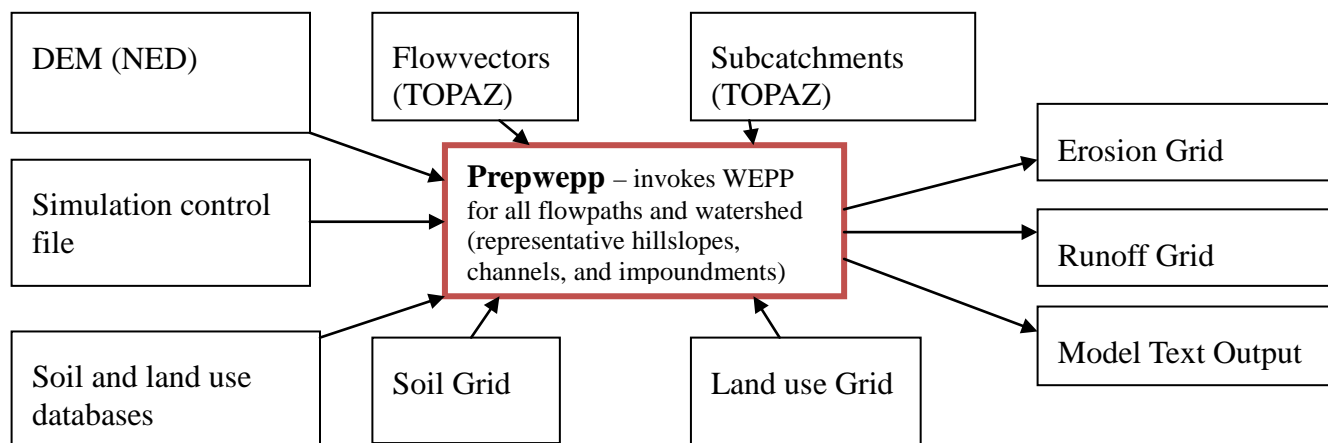
on long term monthly statistics. To account for watersheds at a different elevation from the CLIGEN station, the PRISM (Daly et al., 2004) 800-m gridded monthly averages can first be applied to the monthly statistics before CLIGEN generates daily weather WEPP inputs. The cell containing the watershed outlet is used as the location in the PRISM grid. The closest CLIGEN station monthly statistics are then adjusted to match the PRISM monthly precipitation values, and maximum and minimum temperatures.

## RUNNING THE MODEL

The WEPP model does not have any spatial tracking when running multiple independent hillslopes. Software external to WEPP determines how to map the erosion model output into grid cells. In the case of watershed simulations containing channels, WEPP only processes rectangular hillslope regions and straight channel segments. Results must be mapped back to the subcatchment polygons. The translations from the initial spatial grids to WEPP input files, and coordinating runs followed by the translation from the WEPP text output to spatial grids is controlled by the custom Prepwepp C++ program. Figure 7 shows the data requirements of the Prepwepp program and the resulting processed output.

The Prepwepp program has two distinct methods of running WEPP simulations: flowpath and representative hillslopes (Cochrane and Flanagan, 1999). Example output maps from each of the methods are shown in figures 8 and 9.

**Flowpaths** - For each subcatchment all the flowpaths are determined from TOPAZ flow vectors and a WEPP hillslope is run on each flowpath. Using the land use and soils grid WEPP overland flow element breaks are applied when the land use or soil down a flowpath changes. The detailed soil loss points are mapped back to the spatial area in the subcatchment to determine the erosion value for each cell the flowpath intersects. No channel routing is considered. Typically hundreds of WEPP runs are required to cover a small watershed.



**Figure 7. Prepwepp control program that determines how to build the WEPP input files and map the results to the correct spatial grid cell locations.**

**Representative Hillslopes** - Each TOPAZ subcatchment is associated with a single WEPP hillslope determined by weighting all the flowpaths in the subcatchment. The output sediment yield map displays only a single value for each subcatchment. In addition, runoff from each representative hillslope is displayed. Channel routing from the WEPP watershed simulation mode is used. Typically less than 50 hillslopes are required to cover a small watershed.

## Classifying Results

For detailed flowpath results, WEPP calculates soil erosion down the slope at 100 points. These values are interpolated and mapped to the 30-m cell spacing. The classification involves grouping the results into 10 categories defined by the soil loss tolerance (T) defined by the user. Values less than T are assigned varying shades of green, while values greater than T are assigned shades of red. If sediment deposition occurs in the cell, yellow shading is used. Where flowpaths intersect, weighted results are used to determine the value to assign to the corresponding grid cell. Figures 8 and 9 show erosion maps using a T value of 1 t/ha/yr.

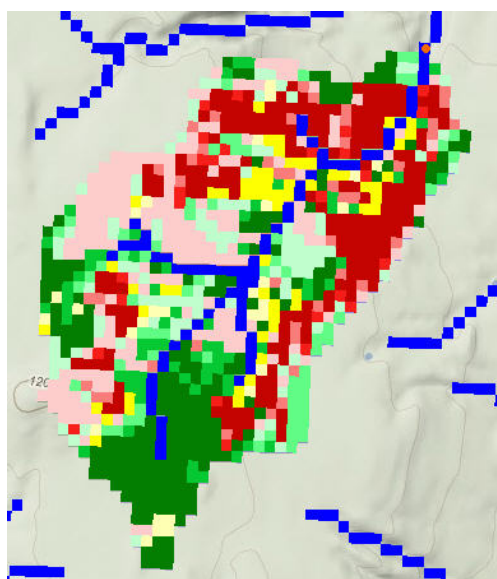


Figure 8. WEPP flowpath simulations grid output. Red indicates areas of greater soil loss.

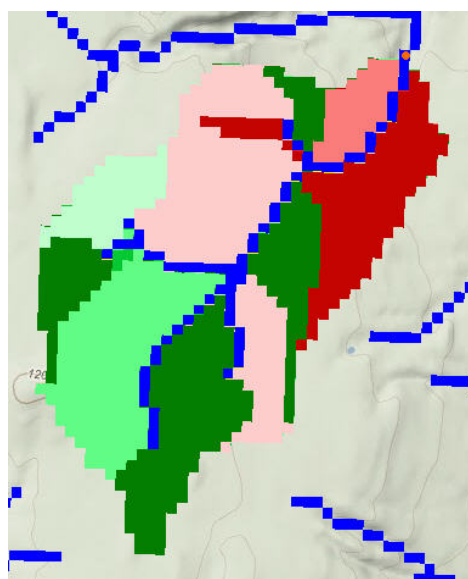


Figure 9. Representative hillslope profile output from WEPP run. Red indicates areas of greater sediment yield.

## CONCLUSION

The Great Lakes WEPP GIS interface adds access to SSURGO soils, hillslope buffers and limited impoundments. Using Google Map images as base map layers allows a user to easily zoom to an area of interest. Complex WEPP watershed simulations can be set up without having to assemble all the data on a local machine. Future work could involve allowing the user to edit other model parameters online, such as land use scenarios and channel properties. Options to use more detailed USGS 10-m DEM data could also be provided. Another improvement could be the ability to upload and use observed climate and topography data. The default set of WEPP land use scenarios are not applicable to all regions of the US, and work is starting to create a more representative WEPP land use database. Ongoing work involves optimizing the simulations for speed to allow more simultaneous users and larger simulation areas.

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