Georeferencing Simulation Objects in RiverWare

Proposal

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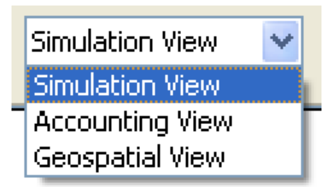
This document proposes a set of new complementary RiverWare capabilities to support georeferencing of simulation objects (SimObjs) within a new "geospatial" workspace view -- a third view of the objects within a RiverWare model (i.e. distinct from the "simulation" and "accounting" schematic views).



0.1 Document Status

02-16-2009: Minor edits.
02-13-2009: Ready for review.

1.0 Overview

The related capabilities proposed in this document support the definition of georeferenced coordinates for simulation objects and address the "clustering" (overlapping icons) problem inherent in depicting objects at their actual geographic locations. These capabilities are:

1. ***Manually positioning*** SimObj Icons on a background map image, loaded from an external image file.
2. ***Automatically positioning*** SimObj Icons -- on a background map image -- with precise numeric coordinates within a known projected coordinate system. Coordinate values would be defined either:
    - by direct entry by the user, or
    - by importing from a GIS source.
3. ***SimObj / Reference Point Callouts.*** In the standard operation of the geospatial workspace, when the user drags a SimObj Icon (along with its text label), the georeferenced location remains fixed -- marked with a bullet -- and a line segment connects the manually placed SimObj / label to the fixed georeferenced location.
4. ***Smart Zooming.*** Icons, labels (and Simobj / Reference Point Callout composites) would be scaled only when zooming out (for a broader view of the model). When zooming in beyond the standard zoom level, icons and labels would remain their natural size (instead of becoming larger) for the purpose of exposing more detail around closely clustered objects.

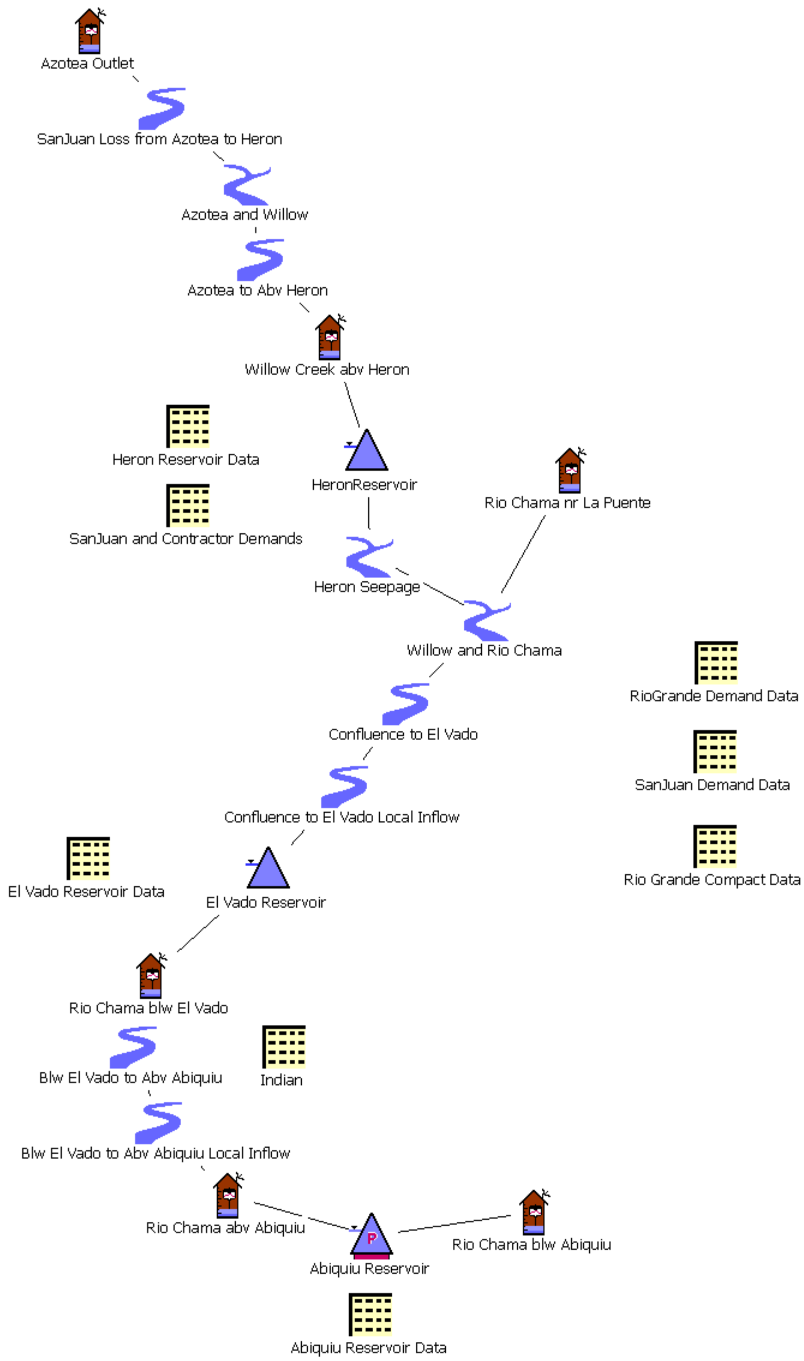
In this proposal, only point coordinates are associated with simulation objects. One could imagine a more involved GIS integration approach where reaches would be represented as lines, and reservoirs and subbasins as regions. Also, hydrologic data could be exchanged through a GIS data interface. Such capabilities should be considered as a GIS integration effort distinct from what is being proposed in this document. The capabilities proposed here may be helpful in developing *requirements* for a more sophisticated GIS integration, but they are not intended to be a basis for such an implementation.

No external API other than Qt4 is required for the capabilities described in this document, with the exception of a simple API to import and export point coordinate data via ESRI shapefiles, an optional feature.

2.0 Comparison of the "Simulation" and "Geospatial" Workspace Views

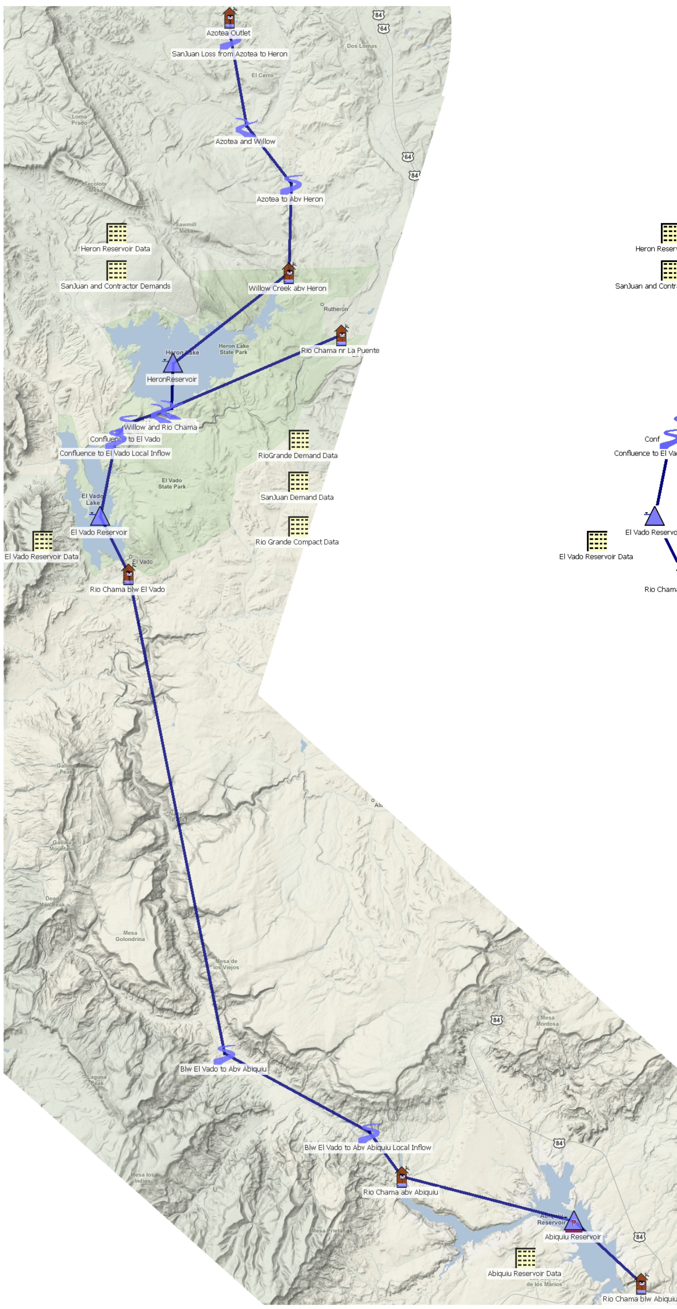
The diagram on this page illustrates the conventional schematic Simulation workspace view.

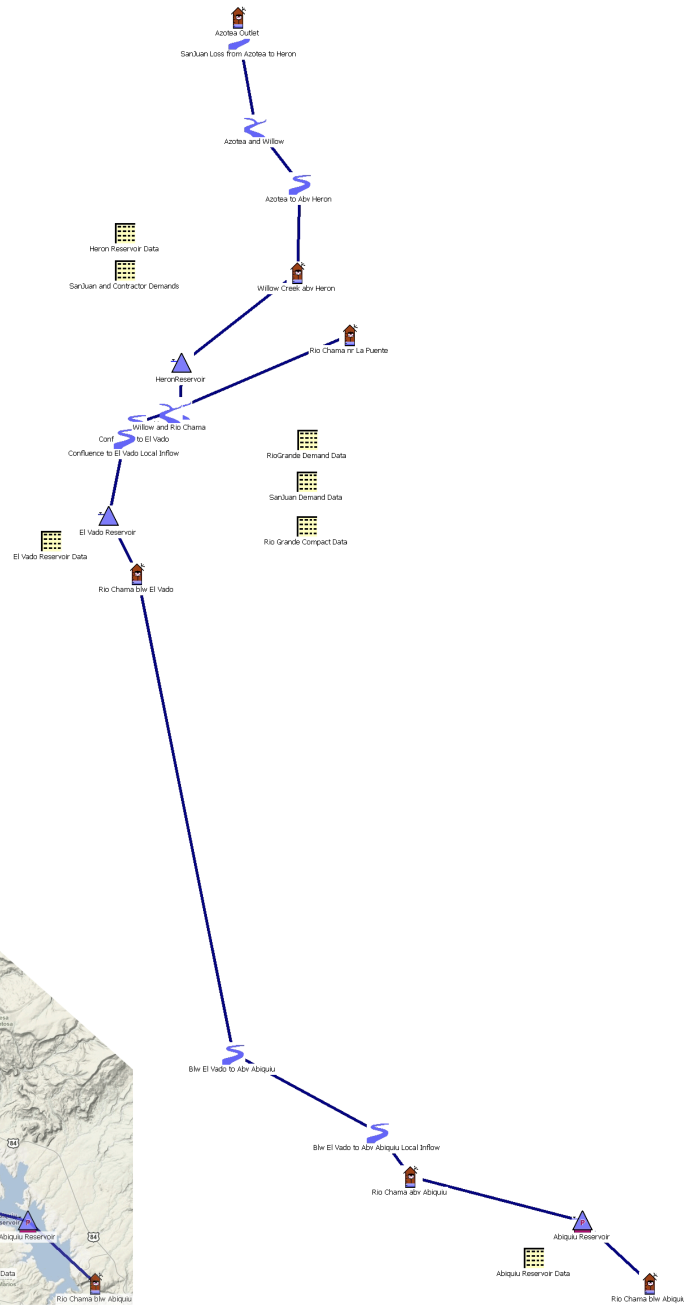
The following page shows two mock-up images of the new Geospatial workspace view -- with and without a background map image -- and **without** application of the *SimObj / Reference Point Callout* feature which addresses the "clustering" problem.



Geospatial workspace view mock-up. See the “clustering” problems at the topmost SimObj icons and between the adjacent reservoirs. See also the clustering problem detail on page 7. This background image example shows terrain. A background image could also be used to illustrate subbasins as solid color regions.

Note: The positions of objects in this mock-up are not necessarily correct -- they were just placed at feasible positions as an illustration.



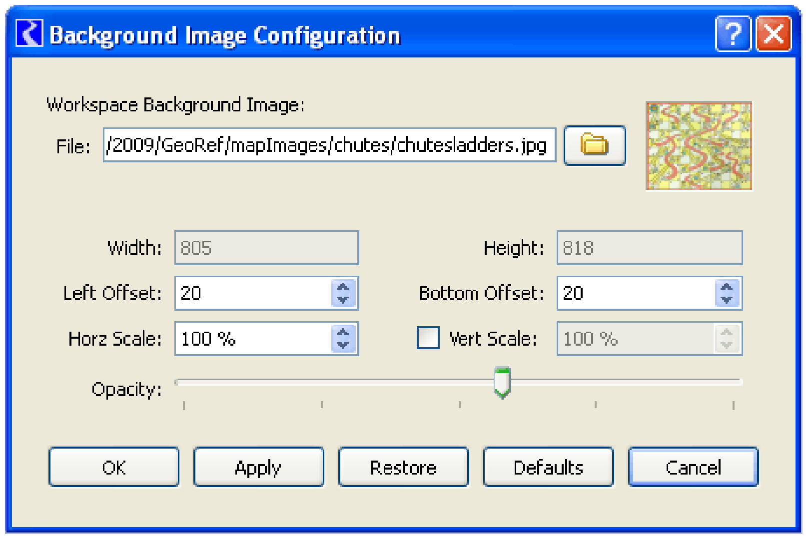


3.0 Relevant Capabilities provided in the Qt4 "Graphics View" Port

Two experimental provisions relevant to this proposal were partially developed during the port of the RiverWare 5.1 Simulation Workspace from a Qt3 "Canvas View" implementation to a Qt4 (version 4.3.3) "Graphics View" implementation.

3.1 Background Image Support

An arbitrary image, loaded from an image file, can be placed behind the new workspace. The user can adjust the scale, bottom and left side offsets (in pixels), and image opacity (fading to the background color).



The illustrated dialog box can be shown from the context menu on the Qt4-implemented workspaces.

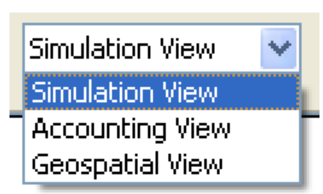
When the user scrolls or zooms the RiverWare workspace, the background image scrolls and zooms appropriately.

In this experimental implementation, the image file reference is *not saved in the RiverWare model file.*

Performance note: The background image feature works well for Microsoft Windows XP. Scrolling and zooming are instantaneous. On Solaris, however (using the X Window System, X11 rev 6.4), the background image has performance problems. Workspace updating and scrolling is quite slow when a background image is displayed.

3.2 Geospatial View (Workspace)

In order to test the independence of distinct instances of the new Qt4-implemented workspace, an additional RiverWare workspace view was developed supporting an independent set of coordinates (distinct from those for the Simulation View). This additional RiverWare workspace view was conveniently called "Geospatial" in anticipation of the possible development of a Geospatial workspace capability.



In this test implementation, Geospatial coordinates are maintained on Simulation Objects, *but are not saved in the RiverWare model.*

4.0 Proposed Capabilities

4.1 Manually positioning SimObj Icons on a background map image

This capability is substantially developed -- see section 3.1 (Background Image Support). Persistence of an image file reference and the configuration data (offsets, scaling, opacity) would need to be implemented.

The background image can be smaller than the RiverWare workspace canvas, which has a default size of 6450 by 6450 pixels. It would be very reasonable to place a map image under only a subset of full model. The positioning of SimObjs outside the background image could be essentially schematic, similar to the standard simulation workspace view.

In general, images should be prepared, or at least used within RiverWare, at a scale which works well with the natural size of SimObj icons (40x40 pixels).

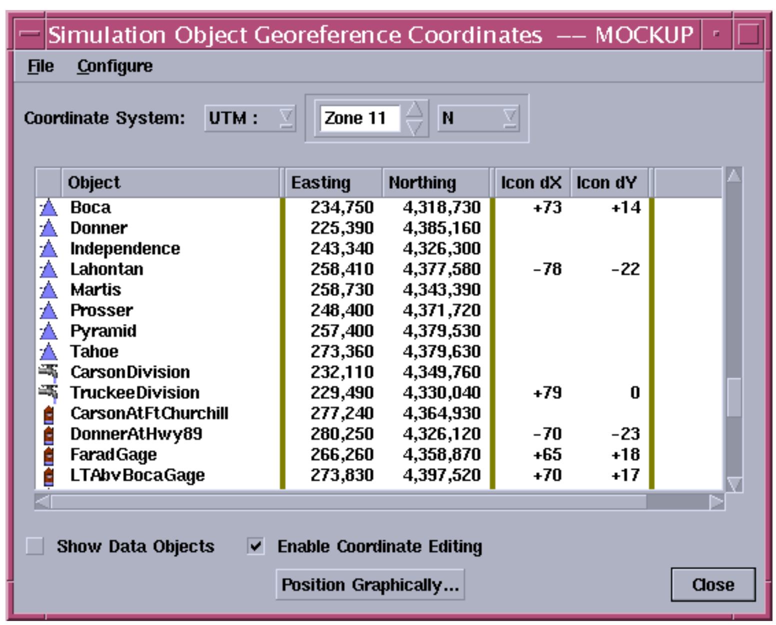
Advanced Option: A RiverWare model could have **more than one associated map image.** All such map images would need to be of the same scale. It would be simplest to support only a set of map images covering exactly the same geographic area (so that the image offsets could also be common).

4.2 Automatically positioning SimObj Icons on a background map image

A loaded image is *calibrated* with its projected coordinate system (e.g. a particular UTM zone) so that SimObj coordinates could be specified numerically (using the same projected coordinate system).

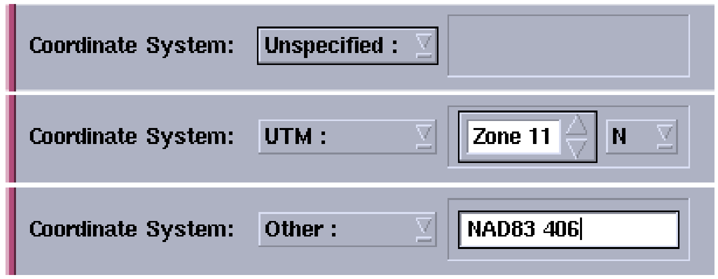
Proposal: Image coordinate calibration is performed by the user by associating precise coordinates with either the edges of the image, or with manually placed reference points within the image. With the assumption that the image is aligned with the coordinate system, the coordinates of two reference points is sufficient. (And with the assumption that scales are the same in both dimensions, with respect to pixels, a single reference point and another coordinate is sufficient).

Advanced Option: Calibration information could be imported with the map image (e.g. from the GIS source which generated the map image). This advanced option is not explored further in this document.



Numerically represented georeferenced SimObj coordinates are viewed and edited in a **coordinate editor dialog,** illustrated with the **mock-up image shown above.** *(This mock-up image shows arbitrary data).* In order to protect the integrity of entered or imported coordinate data, graphical positioning of SimObj coordinates in the Geospatial view (i.e. by dragging the SimObj icon with the mouse) is done only in a special, temporary protected mode.

The indication of the projected coordinate system persists in the model. However, unless coordinate data import (and possibly, export) is supported -- see below -- the projection indication is actually arbitrary. In this case, the projection identification serves only to document the interpretation of the coordinate data, which should be consistent with that of the referenced background map image.



Changing the coordinate system indication within the coordinate editor does not modify SimObj coordinate data.

Once georeferenced coordinate data has been assigned to all SimObjs, different background images generated in the same projection can be used. In general, a re-calibration would be required when loading a different image. (If multiple images are to be supported, distinct calibration information could be persistently associated with each image reference).

In the Geospatial workspace view, once a calibration is defined, the coordinates for the mouse pointer position could be dynamically displayed in the workspace view status bar. This is possible even if a particular projection is not identified, but if one is, it could be indicated as well.

4.2.1 Importing and Exporting Geospatial Coordinate Data

If SimObj geospatial coordinates are defined numerically (rather than graphically by dragging SimObj icons to their apparent correct position on the map image), then the assumption is that the map images being used are generated from a known projected coordinate system -- probably from a GIS source. In some cases, it would be a simple matter to acquire also the point coordinates of simulation objects from the same data source.

Unless a specific requirement for a particular coordinate data format is identified, it would probably be reasonable to support importing, and possibly exporting simulation object point coordinate data via **ESRI shapefiles.**

Technically, an ESRI shapefile is a small set of files. These are files -- some binary and some text -- with a mostly-open specification (slightly nuts: the main ".shp" binary file has a mix of big-endian and little-endian byte ordered fields). Data is flat -- there is no topological or hierarchical structure. A shapefile represents a collection of unrelated points and lines and polygons, although in practice, a given shapefile represents only one of those types (e.g. points). The attribute file (".dbf", e.g. for the SimObj names) uses the dBase III format. Use of the optional projection (".prj") file would be technically correct, though perhaps unnecessary -- it could be left up to the user to insure that the intended projected coordinate system is used.

It's possible that some of the RiverWare DMI name map capabilities could be leveraged to map object names, if the names of objects from the external source would not necessarily be the same as the names of objects in RiverWare.

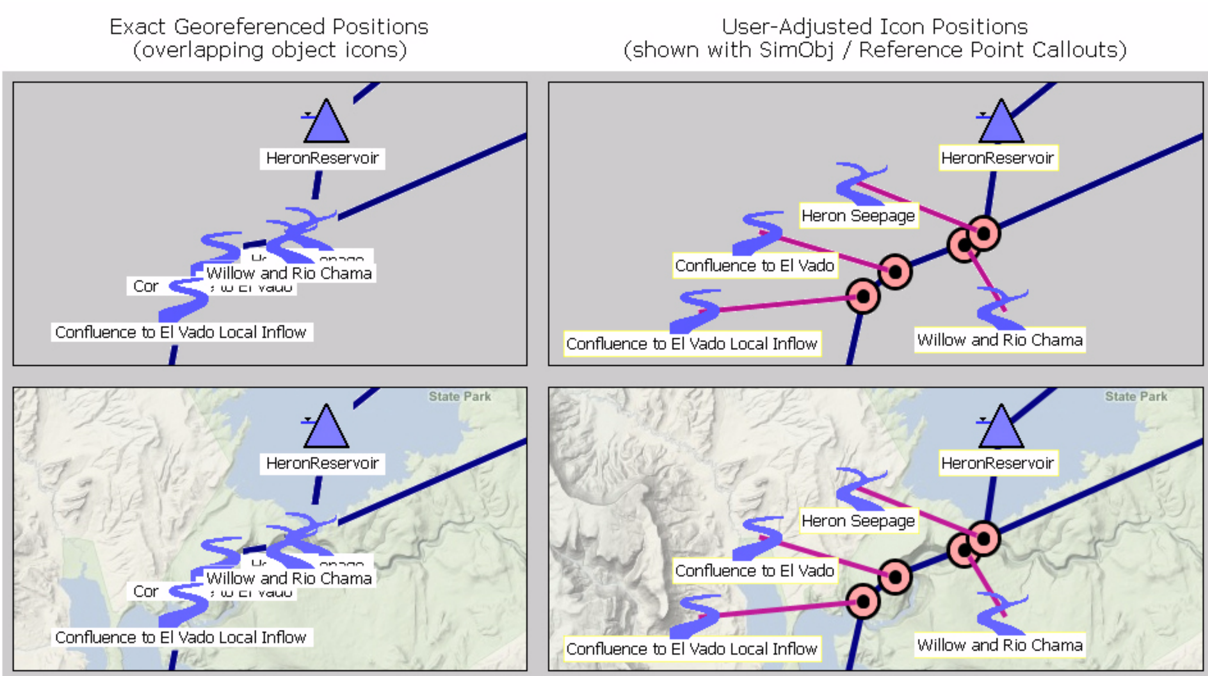
I would recommend that a simple open source shapefile API be used rather than rolling our own. Here are two possibilities:

- **Shapefile (Shapelib) C Library V1.2** (http://shapelib.maptools.org/) -- a simple ANSI C API which supports only the major file components (.shp, .shx, and .dbf). *There is no support for projection (.prj) files.*
- The **OGR Simple Features Library** (http://www.gdal.org/ogr/), an open source C++ library which provides access to a variety of vector file formats, including ESRI shapefiles.

4.3 SimObj / Reference Point Callouts

A difficulty with georeferenced positions of simulation objects in a RiverWare model is that there will often be clusters of SimObj icons piled up on top of each other.

The following mock-up illustrates the use of "Callouts" which are created when the user drags the SimObj icon and label away from its georeferenced position -- to a position where it is not obscured by other features.



If the SimObj icon is dragged back, close to its associated georeferenced point, the SimObj will "snap" back to that point, effectively replacing the reference point.

This "callout" dragging behavior is the default SimObj icon dragging behavior within the geospatial workspace view.

The user may, at times, want to define the georeferenced coordinates by dragging the SimObj icon (or the georeferenced target icon, if that is shown for a particular SimObj). This is implemented in a special temporary mode initiated by an explicit GUI operation (including from the coordinate editor, see dialog mock-up in the preceding section) and indicated with a brightly colored toolbar along the bottom of the workspace view window. The toolbar has *accept, reject,* and *dismiss* buttons. Changes must be accepted or rejected before the dismiss button can be operated.

4.4 Smart Zooming.

SimObj Icons and their attached labels are scaled only when *zooming out* to see a broader view of the model. When *zooming in* beyond the standard zoom level, icons and labels remain their natural size (instead of becoming larger) for the purpose of exposing more detail around closely clustered objects.

Smart Zooming *zoom-in* non-scaling also applies to **SimObj Icon / Reference Point Callouts.** The displacement between the SimObj icon and the Reference Point target icon -- when zoomed in -- *will remain constant, as measured in pixel distances.* (It would make no sense to zoom into a reference point, and have the connected SimObj Icon and label off of the screen). The Callout's pixel displacement is illustrated in the coordinate editor dialog mock-up -- *detail repeated to the right* -- see the **Icon dX** and **Icon dY columns.**

Object	Easting	Northing	Icon dX	Icon dY
Boca	234,750	4,318,730	+73	+14
Donner	225,390	4,385,160		
Independence	243,340	4,326,300		
Lahontan	258,410	4,377,580	-78	-22
Martis	258,730	4,343,390		
Prosser	248,400	4,371,720		
Pyramid	257,400	4,379,530		
Tahoe	273,360	4,379,630		
CarsonDivision	232,110	4,349,760		
TruckeeDivision	229,490	4,330,040	+79	0
CarsonAtFtChurchill	277,240	4,364,930		
DonnerAtHwy89	280,250	4,326,120	-70	-23
FaradGage	266,260	4,358,870	+65	+18
LTAbvBocaGage	273,830	4,397,520	+70	+17

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