Georeferencing Quality Control of Ontario's Water Well Data Base for the Greater Toronto and Oak Ridges Moraine Areas of Southern Ontario

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Abstract

The Ontario Ministry of Environment and Energy (MOEE) is the custodian of a digital database of the water wells log drilled in the province. The lithological, material properties and hydrogeologic information contained in this database is utilized extensively in geotechnical and hydrogeologic site investigations and for geologic and terrain studies. The utility of this database is however restricted, owing in part to planimetric and elevation inaccuracies associated with these records.

An automated process has been used to flag positional errors in this database for a large part of the Greater Toronto, and Oak Ridges Moraine areas of southern Ontario using GIS processing techniques. All records in the database are spatially referenced by UTM coordinates, Lot and Concession coordinates, and elevation. For each water well within the study area, its UTM coordinates were spatially compared to its Lot and Concession coordinates. Where discrepancies between the two planimetric geo-referenced sources were encountered the record was flagged as being locationally inaccurate.

To verify the surface elevations of these same records, a quality controlled Digital Elevation Model (DEM) was constructed, providing a continuous surface elevation datum. The surface elevation of each well was then compared to the DEM and where differences of 10 metres or greater were encountered, the record was flagged as having a locational error. The results of these processing steps indicate that of 56,923 water well records in the study area, 18 percent of these records have planimetric coding errors, 14 percent have incorrect or incomplete elevation values and 27 percent of records have planimetric and/or elevation inaccuracies.

1.0 Introduction

The Greater Toronto Area (GTA) (figure 1) of southern Ontario as one of the fastest growing regions in Canada is experiencing intense development pressures. The current population of 4.5 million is expected to increase to over 5.2 million by the year 2001 (Golden 1996). To minimize the environmental impact of this increasing population density on the natural resources and environmental health of this region proper planning is required. Planning that is respective of the environment, is predicated on accurate and comprehensive resource information, which is not always available throughout the GTA. This is particularly the case in the subsurface, where there is a recognized void in geological and hydrogeologic knowledge (Oak Ridges Moraine Technical Working Committee 1991).

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Groundwater in this area is a significant renewable natural resource. Running directly through the GTA is the Oak Ridges Moraine (ORM), a large unconfined surficial material aquifer, composed of predominately of glaciofluvial and ice-contact sands and gravels (Barnett 1992, Barnett et. al. 1997, Sharpe et. al. 1994, 1996) (figure 1). This aquifer is used extensively as a fresh water source by numerous communities, rural residents and industrial and farming operations. This feature is exposed at surface in the highest elevation areas (corresponding to the Lake Simcoe - Lake Ontario drainage divide) creating an extensive groundwater recharge zone dissecting the GTA. It is suspected the groundwater resources in this area are underutilized, but with the lack of subsurface geological and hydrogeological knowledge this has been difficult to demonstrate (Sharpe et. al. 1996). Protection of this aquifer complex is as well impeded by the lack of subsurface geological knowledge.

The development pressures in this area combined with the lack of geological understanding prompted the Geological Survey of Canada in co-operation with the Ontario Geological Survey to initiate the Oak Ridges Moraine NATMAP (NATional MApping Program) in 1993. Two fundamental objectives of this study were to gain an understanding of the location, size and potential of subsurface aquifers and to develop an understanding of the control, surface and subsurface geological conditions exert on groundwater movements through this region. In support of these objectives, a comprehensive subsurface database for the GTA/ORM areas is being compiled (Russell et. al. 1996). Geotechnical and hydrogeological data from numerous sources have been integrated into this database including data from the Ontario Ministries of Transportation, Environment and Energy, and Northern Development and Mines, Ontario Hydro, Geological Survey of Canada, Interim Waste authority (IWA), Geotechnical and Environmental consultant companies and Universities. By far the largest and most spatially distributed component of this database has been derived from the Ontario Ministry of Environment and Energy's (MOEE) water well data base.

2.0 The MOEE Water Well Database

Since 1946, as a result of Ontario government legislation, it has been mandatory that following construction of new water wells that drillers submit standardized well records to the MOEE. This database, now at over 400,000 records, contains a full description of well geo-referencing, geological formations encountered during drilling, subsurface water characteristics, details of the well construction and testing and well yield results (Ontario Ministry of the Environment 1977). A large part of this database, but not all, has been entered into a digital database. For the Greater Toronto (excepting Halton Region) and Oak Ridges Moraine areas, the digital portion of this database contains 56,923 well records.

The digital database resides in a flat file structure, containing some 206 attribute fields. The georeferencing portion of this database includes, the landowners name and address, UTM coordinates, municipal coordinates (township, lot and concession), well elevation at surface and watershed. It has for some time been recognized that this database contains significant georeferencing errors which has resulted in users having a reduced confidence in this database. There is however redundancy in the well georeferencing that allows for these records to be

queried in a GIS for apparent geocoding errors (Hunter and Beck 1996). There has recently been several refinements made to this database, including an MOEE GPS survey of 1982-1992 water wells in York Region and planimetric refinements to well UTM coordinates in the central portion of the ORM area by Hunter and Associates in 1996. These most recently available updates to the MOEE water well database have been used for analysis in this study.

3.0 Georeferencing Error Checking Methodology and GIS Processing

Two separate georeferencing checking procedures were employed for the 56,923 water well records in the GTA (except Halton region)/ORM areas (figure 2), a planimetric verification and an elevation verification. The planimetric verification involved spatially checking the UTM coordinates of each well against the recorded municipal coordinates (Lot and Concession values). The elevation checking involved using the UTM coordinates of each well to extract elevation values from a Digital Elevation Model (DEM) and then comparing these values to the recorded well elevations. This process was developed and first employed by Hunter and Associates in georeference quality controlling of water wells, in the central portion of the Oak Ridges Moraine in contract work to the Ontario Ministry of Natural Resources and Region of Durham (Hunter and Beck 1996, Oak Ridges Moraine Technical Working Committee 1991). Hunter and Beck (1996) in their work in the central portion of Oak Ridges Moraine employed 1:10,000 scale Ontario Basic Mapping (110 map sheets) in developing a DEM.

The reference spatial data necessary for this checking, a polygon cadastral cover and a regional DEM, were however not available for the complete area, and therefore had to be generated prior to any georeferencing checking. Functions of a GIS, as described below were used to generate both a 1:10,000 scale polygon cadastral cover and a 1:50,000 scale DEM derived using National Topographic Series mapping

3.1 Cadastral Fabric Generation

Ontario Basic Mapping (OBM) is compiled on 20 different covers at a 1:10,000 scale for most, but not all areas, of southern Ontario. The OBM cadastral information in its current format, is contained in two covers, a vector cover containing Township, Lot and Concession boundaries and a point cover containing the Township, Lot and Concession attributes (Ontario Ministry of Natural Resources 1994, 1996). A quality controlled polygon Cadastral cover has not been developed. To spatially query the OBM for cadastral information therefore necessitated a structured polygon cover be created.

It was considered beyond the scope of this project to develop a quality controlled cadastral polygon cover from the OBM data. The OBM data were essentially used in an “as is” condition at the time of this work (March 1997). In order to develop the polygon cadastral cover, hand editing of both the vector and point attribute data was necessary. In developing the cadastral polygon cover, a reasonable amount of care was taken to rectify errors encountered in these data and not introduce additional errors. In most cases rectification of errors was accomplished by identifying the most logical cause of the problem and correcting it. To generate cadastral

topology for individual OBM maps was relatively easy, but this was however not the case when attempting to generate topology for several OBMs. It was found that the removal of OBM internal neatlines, not only resulted in multiple attributes per polygon but created additional unclosed polygons that could not easily be resolved without hand editing. As a time saving measure and for accuracy reasons, the internal neatlines were left in place and became part of the developed polygon cover. By not removing the internal neatlines, the number of polygons nearly doubled. The resultant polygon cadastral cover for the GTA/ORM areas was constructed from an area covering 571 OBM maps and is composed of over 24,000 individual polygons (figure 1). Of the 571 OBM maps covering this area, 36 were unavailable at the time of this study and 4 maps contained corrupted cadastral information (figure 1).

3.2 Digital Elevation Model Generation

As part of the broader NATMAP project a quality controlled, 30 metre grid resolution DEM, derived using 1:50,000 scale NTS digital map sheets was developed for a 32,000 square kilometre area, centred on the Greater Toronto/Oak Ridges Moraine Areas (Figure 3). This model is being used to serve a number of functions in the project, including ortho-rectification of satellite imagery, watershed analysis (Paquette et. al. 1997a, 1997b), hydrologic and hydrogeologic mapping (Hinton 1996), and Quaternary and terrain mapping (Moore et. al. 1996, Barnett et. al. 1997, Kenny et. at. 1997a). This model has been employed here to provide a surface datum for comparison with elevation values in the MOEE water well database.

This model has been developed using the most rigorous standards available (United States Geological Survey, 1990) and the most advanced DEM processing methods (Hutchinson 1989, 1993). By proper application of terrain specific interpolation algorithms and drainage enforcement techniques, significant DEM accuracy improvements can be obtained relative to models developed using traditional DEM generation techniques (Hutchinson 1993). The extra effort in generating this model ensured the development of an accurate model that can be used confidently for quantitative analysis. To assist in quantifying the accuracy of this model, it has been statistically compared to Geodetic Survey of Canada benchmark data. Results of this verification indicates a sound model: a standard deviation of 2.87 metres with only 4 of 414 control points having a deviation of greater than 10 metres. The complete processes used in the generation of this model and further quantification estimates of its accuracy are in the process of being documented (Kenny et. al. 1997b).

4.0 Results

With the OBM cadastral polygon cover created, a point to polygon query using the MOEE water well UTM coordinates for each well yielded the corresponding OBM Lot and Concession coordinates. These OBM cadastral coordinates were then brought into the MOEE database and used in a comparative query with the recorded water well cadastral coordinates. Results of these queries, shown graphically in figure 4, and in tabular form in table 1, indicate that 77 percent of the MOEE water wells have cadastral and UTM coordinate agreement, 18 percent of the records

are in disagreement and 5 percent of the results were inconclusive. Inconclusive results were obtained, for several reasons, including; incomplete or invalid Lot and Concession values in either or both MOEE and OBM sources, invalid UTM zones in the water well database, well lies within a surveyed town (i.e. no Lot and Concession values). Each of these cases were documented and a planimetric attribute (Plancode) was developed and applied to each well in the study area (table 1).

By using the developed DEM as a surface datum, the UTM coordinates for each well were used to extract the DEM elevation values. To increase the elevation accuracy of this sampling, a cubic convolution sampling method was used to extract elevation values from the raster DEM. With these elevation values extracted, they were then brought into the MOEE database for comparative analysis with the surface elevation values recorded for each well. Analysis of these results (figure 5, table 2) reveal that 86 percent of the wells have recorded elevations within 10 metres of the DEM and 7 percent have differences of greater than 10 metres. The remaining 7 percent of records yielded inconclusive results, largely the result of null or zero elevation values in the MOEE database. Hunter and Beck (1996), reported comparable results.

5.0 Conclusions

The results of the georeferencing checking completed here indicate that 70 percent of the records in the MOEE water well database in this part of Ontario have both correct planimetric and elevation georeferencing coordinates. More importantly however, this study has found that 27 percent of the records are suspected of having georeferencing errors. Users of this database may find it sufficient to simply avoid using these records or at least when using these records, to use them with caution.

The DEM extracted elevation values could also be used for updating well records, particularly in cases where zero or null values are contained in the MOEE database. Of the 3026 well records containing either null or zero values for elevation, 2432 have valid planimetric coordinates, many of these resultant from the MOEE York Region GPS survey where elevation values were not recorded. These records could easily be updated to include the DEM derived elevation values.

All results obtained here are referenced through the MOEE water well primary database key, thereby allowing for easy integration of these results into the MOEE database as a relational table. In addition to archiving the developed planimetric and elevation georeferencing quality control attributes (tables 1 and 2) as described previously, the raw values returned from the OBM cadastral cover and the DEM are also archived. Archiving these additional attributes allows users of the database the flexibility to view or use these data as is necessary in their application. The results obtained and documented here, should give users of the MOEE water well database an increased confidence in the georeferencing quality of these data.

Acknowledgments:

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Table 1. Developed Planimetric attribute (Plancode) describing the results of the planimetric checking of the MOEE water well records versus the OBM derived cadastral cover.

Value	Occurrences	Description
1	939	Incorrect MOEE UTM zone, null MOEE UTM Easting or Northing
2	377	MOEE UTM coding error - Well far outside area
3	90	OBM cadastral fabric corrupted
4	55	No OBM cadastral attributes
5	369	Well lies within lake or river
6	50	Well lies within park
7	793	Digital OBM maps unavailable
8	411	MOEE LOT/CON coordinates contains null values
9	65	OBM cadastral fabric contains null values
10	1259	Both OBM and MOEE LOT/CON coordinates contain null values
11	43738	Agreement between MOEE and OBM Lot and Concession values
12	8525	Disagreement between MOEE and OBM Lot and Concession values
13	239	Well lies within City that does not have Lot and Concession coordinates
14	13	Well lies within either a City of lake (e.g. Toronto waterfront)
Total	56,923	

Table 2. Developed Elevation attribute (Elevcode), describing the results of elevation verification of MOEE waterwell records versus a 1:50,000 developed DEM.

Value	Occurrences	Description
1	939	Incorrect MOEE UTM zone, null MOEE UTM Easting or Northing
2	377	MOEE UTM coding error - Well far outside area
3	3,026	Null or Zero MOEE well elevation value
5	41,935	Well Elevation and DEM within 5 metres
6	6,877	Well Elevation and DEM within 5 to 10 metres
7	1,397	Well Elevation and DEM within 10 to 15 metres
8	2,372	Well Elevation and DEM difference greater than 15 metres
Total	56,923	

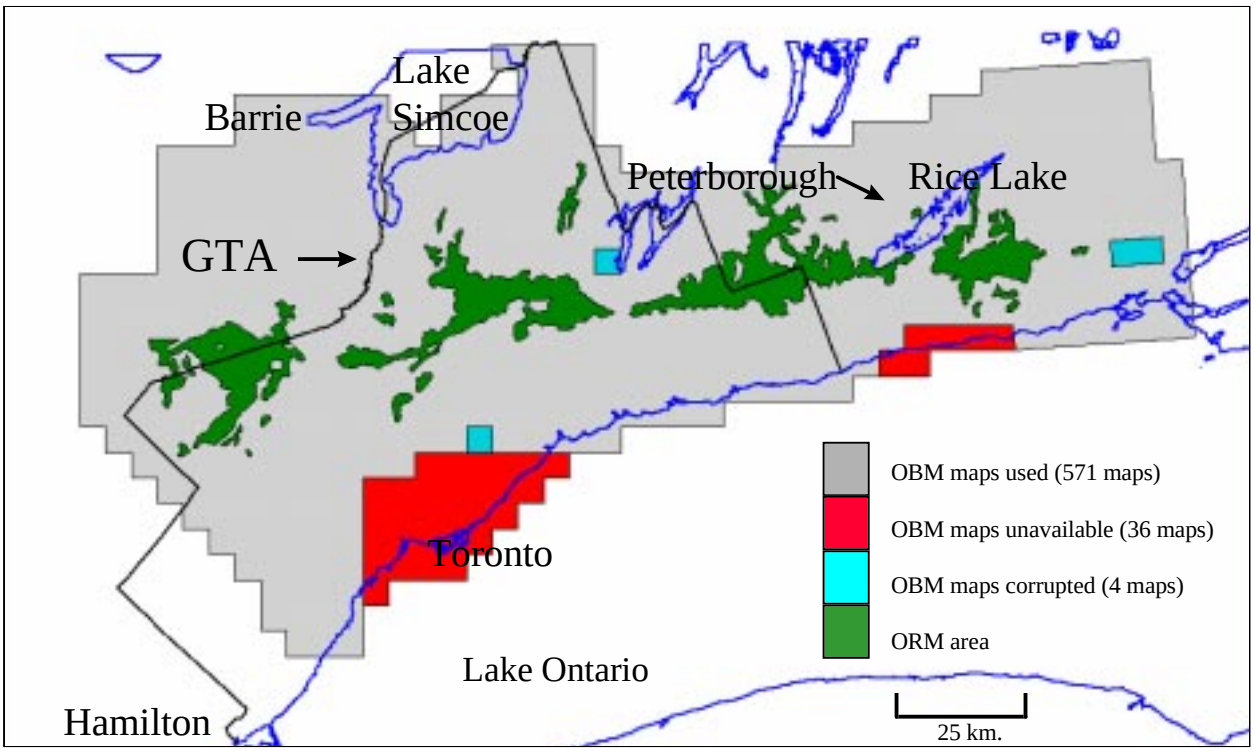

Figure 1. Location map showing the geographic extents of the GTA and ORM in south central Ontario. Map also showing the distribution and status of OBM maps used in the generation of a 1:10,000 scale Cadastral cover.

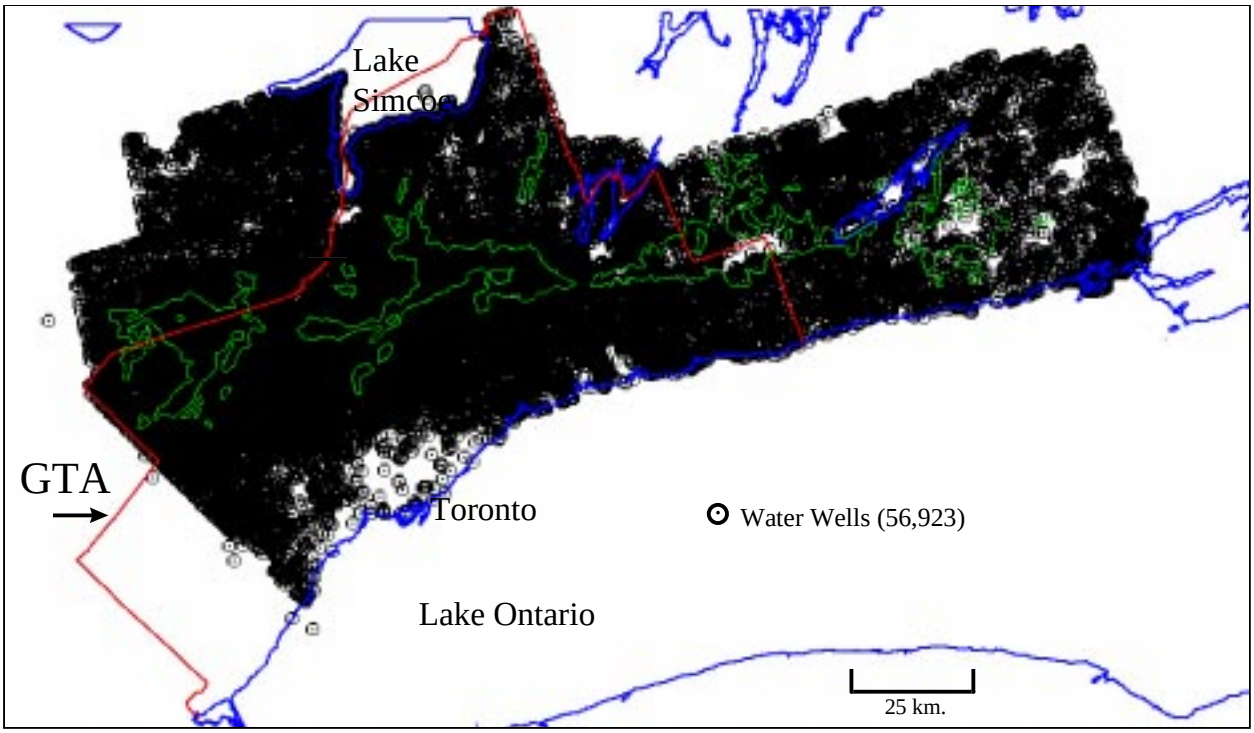

Figure 2. Location map showing the distribution of digital MOEE Water Well records for the GTA (except Halton region) and ORM areas.

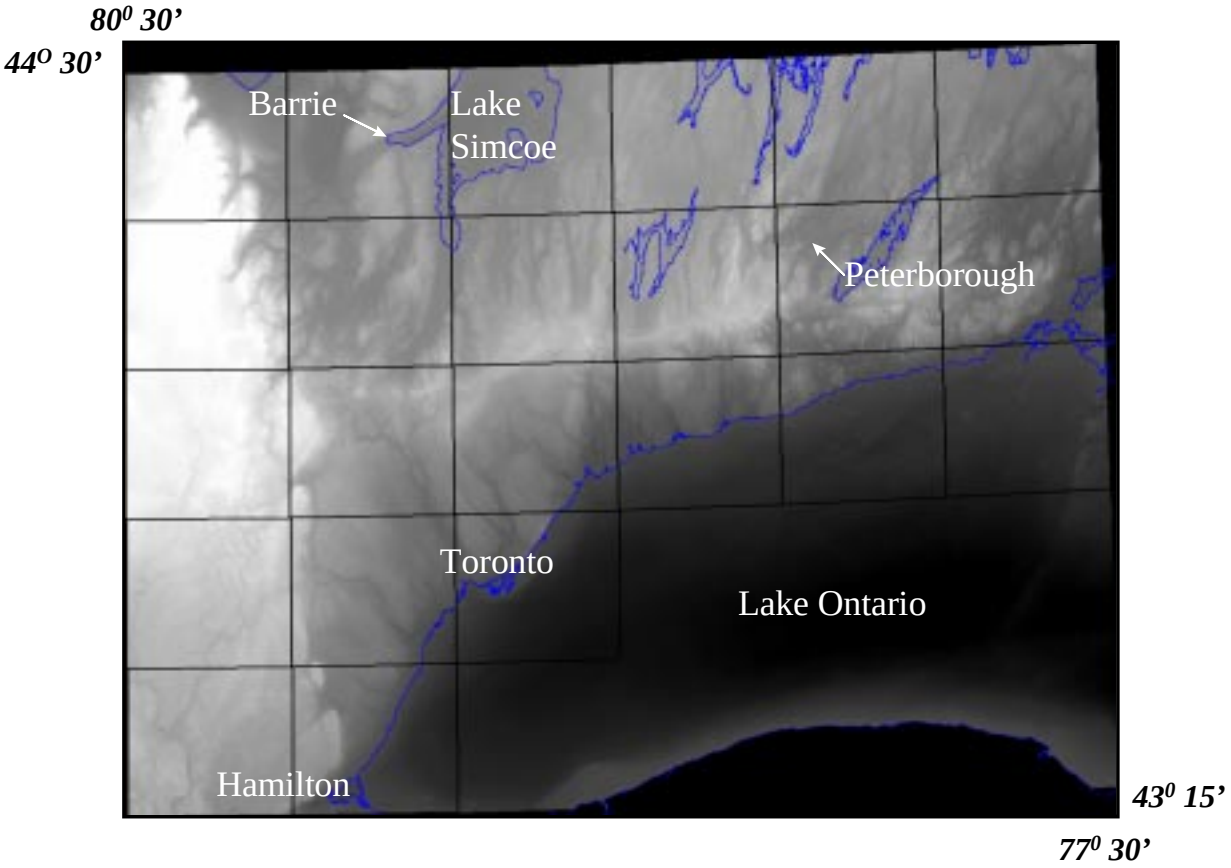

Figure 3. Digital Elevation Model for the Greater Toronto/Oak Ridges Areas. Model Developed using primarily 1:50,000 scale NTS maps.

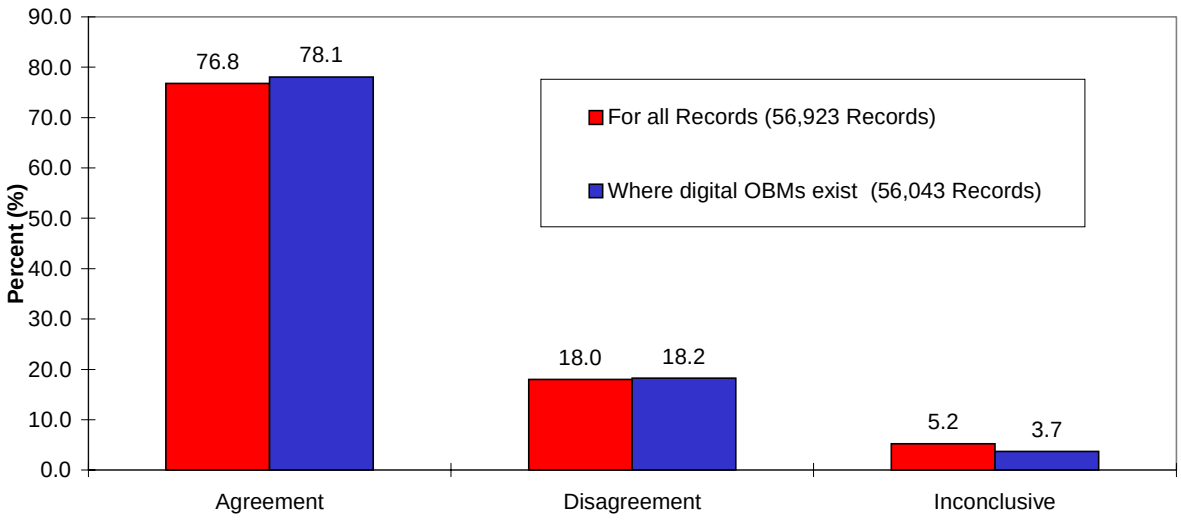

Figure 4. Results of positional verification of MOEE water well Lot and Concession coordinates versus OBM Lot and Concession coordinates for 56,923 records in the GTA/ORM areas.

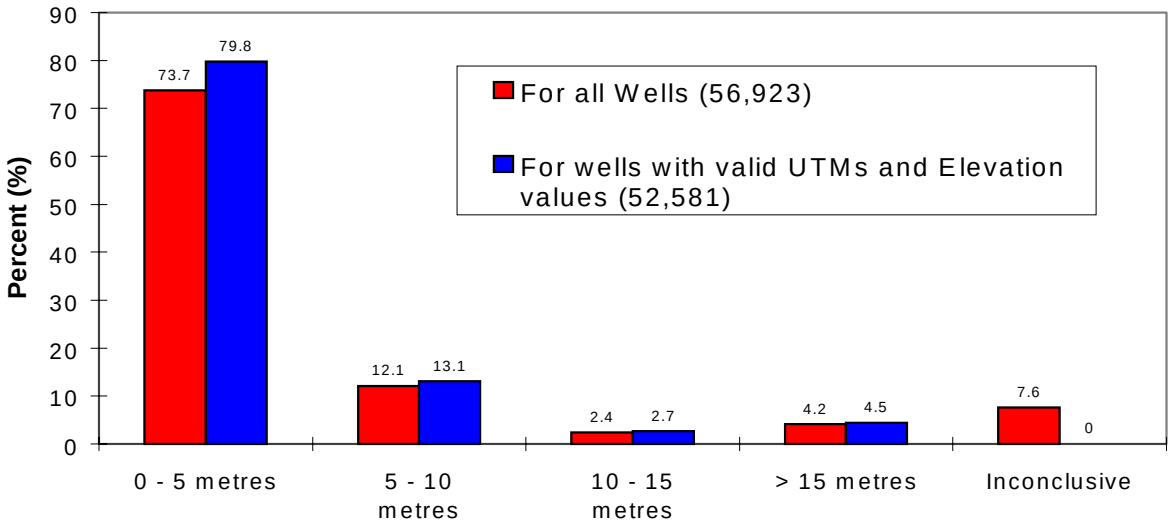

Figure 5. Results of Elevation verification of MOEE water well records. Comparison to a 1:50,000 scale, 30 metre grid DEM.