Narragansett Bay
Research Reserve

Technical Report

2011:2

A Report of the Prudence Island Groundwater Task Force

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Introduction

There have been a number of studies conducted on Prudence Island related to its groundwater resource and, as a result, there is reason to believe that current and projected demand exceeds the available supply. Concerns about continued development and a shift from primarily seasonal to year-round use of existing homes led to the establishment of a Prudence Island Groundwater Task Force (PIGWTF) in 2005. The PIGWTF represented a number of island organizations including the Narragansett Bay National Estuarine Research Reserve (NBNERR), Prudence Island Water District (PIWD), Prudence Island Planning Commission (PIPC), and the Prudence Conservancy (PC). The Town of Portsmouth also participated in the PIGWTF for a short period of time. Activities undertaken by the PIGWTF included a complete review of past studies, informational meetings with U.S. Geological Survey (USGS) and various state agency representatives to express concerns and seek input regarding next steps, community workshops, presentations to the Portsmouth Town Council, contribution to a community survey, support of an independent study by a University of Rhode Island (URI) professor, and monthly monitoring of groundwater level and stream flow in widely dispersed Island wells and streams. Although the PIGWTF is no longer a functioning body, this report has been generated to document past task force activities and serves as a reference for ongoing efforts (primarily monitoring) as well as any additional future studies conducted to investigate the Island's groundwater resource.

Task Force Activities and Outcomes

The following identifies a series of tasks and their outcomes undertaken by the PIGWTF from its inception to the present. Each activity is presented as an overview for general informational purposes and may lack complete documentation. Additional information may be available upon request.

Literature Review

Studies related to Prudence Island's groundwater resource carried out over a period of 13 years (1992-2004) were reviewed to evaluate its current status and determine whether concerns regarding changing patterns of use and additional development were justified. Executive summaries of the two most extensive groundwater studies conducted on Prudence Island are included in Appendix 1. From all past studies, a number of inferences can be drawn that suggest that there is reason for concern; specifically, that the groundwater resource may not be sufficient to meet current and future supply demands. The reader is cautioned to review past studies in their entirety to ensure a more complete understanding of the issues / concerns expressed. Past studies also suggest a number of mechanisms for protecting this resource as well as identifying a need for additional resource evaluation.

Inferences from past studies

- Mill Creek basin is at or exceeding capacity
  Withdrawals should be limited to 1992 quantities to maintain ecological function in Mill Creek (Urish, 1992); Mill Creek watershed basin on the verge of being utilized beyond safe yield (Pare Engineering Corp., 1998)
- Current well locations are vulnerable to contamination
  Analysis of surface water samples revealed a slight degradation in water quality due to anthropogenic activities (Chatterton, 1994); current development often occurs on marginal land with high seasonal groundwater levels (personal observation)
- Potential for salt water intrusion
  Community well depths are well below mean sea level and all respond to tidal fluctuations; location of primary wells near the northern boundary of the Mill Creek

watershed and proximate fractures leading to the shore may limit water producing potential (Urish, 2004)

- Decline in groundwater levels
  Estimated 6" annual decline in groundwater levels at primary community well heads (Urish, 2004)
- Expanding area of contribution
  Decrease in summer water temperatures between and within each of two study years implies groundwater drawn from greater depths (Urish, 2004)
- Contributing bedrock fractures and flow paths are complex and poorly known
  Trace fracture maps based on aerial photo interpretation and surface lineaments may not correlate to subsurface features (Degnan et al., 2002; Moore et al., 2002); recommend borehole testing to locate major fractures (GZA Environmental, 1999)

Recommendations from past studies

- Increase storage capacity
- Establish leak detection program
- Maintain strong water use controls
- Monitor salinity
- Pursue construction of an additional backup well outside of the Mill Creek watershed
- Conduct groundwater level monitoring

A number of study recommendations have been implemented. A new 100,000 gallon storage tank was installed in 2003 by the Prudence Island Utility Corporation (PIUC) on Hillside Road to reduce pressure on the system during periods of peak demand. The PIWD has implemented a leak detection program and successfully discovered and reduced water loss via distribution line leakage. Finally, monthly volunteer monitoring for groundwater levels (initiated in 2006) is ongoing.

An interview with Dr. Daniel Urish, the primary author of the majority of past studies, was also conducted in an effort to better understand study results. Dr. Urish cautioned that, in addition to the stated results of studies and questions these results raise, further investigations would be necessary to determine whether the annual decline in average groundwater levels in community wells were a function of local drawdown at the well head or simply reflect that groundwater levels had not yet reached equilibrium between recharge and withdrawal at the [then] newly installed well heads.

Dr. Urish also discussed concerns associated with the transport of water outside the Mill Creek watershed where the two primary community wells are located. In areas that are not serviced by sewer lines, residential water use typically represents a component of aquifer recharge since as much as 70 percent of water used is returned via septic system infiltration. On Prudence Island, most homes (~80% in 2004) that have PIWD service are located outside of the Mill Creek watershed resulting in a potentially greater net loss (Figure 1). The extent to which the transport of water out of the watershed contributes to a general decline in water levels is not known since the geographic extent of the recharge area may or may not be equivalent to the watershed boundary. Unlike typical aquifers which are defined by the amount and extent of materials such as sand and gravel, our groundwater resource is contained within bedrock fractures.

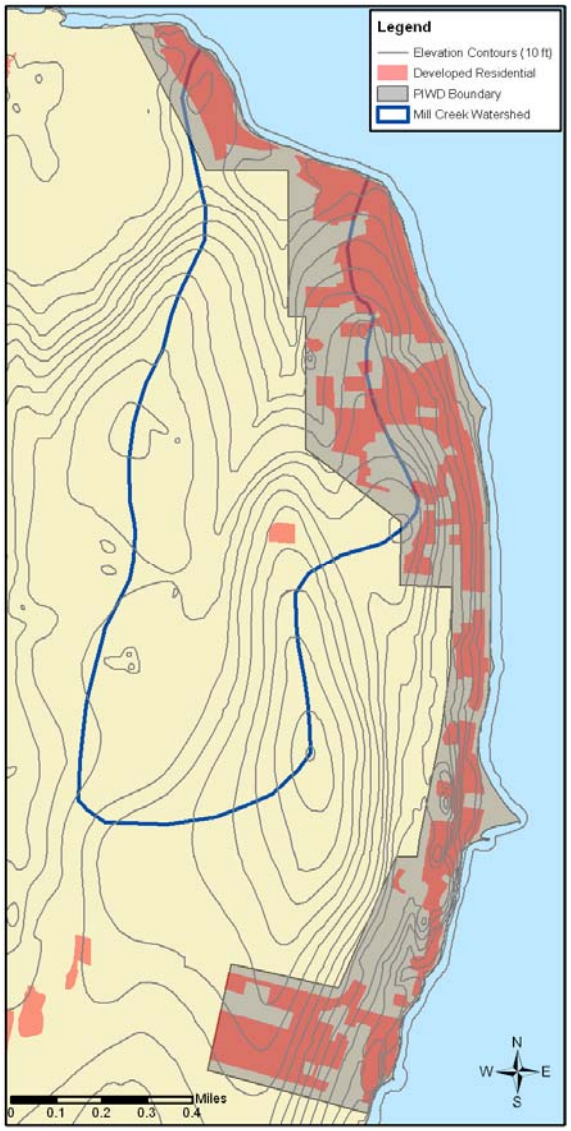

Figure 1: Potential for groundwater resource loss as the result of transport outside the Mill Creek watershed.

Evaluating Development Pressure

In addition to development pressures associated with the building of new homes, Prudence Island has also experienced pressures resulting from a change in traditional use. Specifically, there are three major drivers which have altered demands for groundwater in recent decades:

- Summer residents have become three or four season residents, especially on weekends
- Summer residents have retired and now live on the island full-time
- Employed weekend residents have become full-time residents who commute to their workplace or telecommute

Due to interruptions in service as the result of increased demand and limitations in the water system infrastructure of the PIUC (which developed and maintained the community water service prior to the establishment of the PIWD), a moratorium on additional service connections was imposed in 1989 pending a groundwater availability study. The subsequent study recommended that the moratorium remain in effect until new wells were installed, new water resources were identified, and improvements were made to the PIUC system (Urish, 1992). For a more complete overview of the status of the moratorium and requirements established by the Public Utilities Commission for lifting it, see the referenced report of the Public Utilities Commission (2000).

In 2005, the Portsmouth Planning Department conducted a build-out analysis for Prudence Island (Figure 2). The analysis was performed using a public access extension for ArcView 3.x which bases build-out density on acreage estimates of parcels (by zoning district) with restrictions implemented for building constraints such as wetland areas and infrastructure requirements for larger parcels. The derived values were intended for use as a planning tool and not as a predictor of future growth. However, they do prove useful for visualizing development potential on the island.

In addition to the 409 built-out parcels present at the time of the analysis (those with existing structures which are too small for further subdivision) an additional 629 homes were estimated to be possible at full build-out (Table 1). These included vacant substandard sized lots (grandfathered parcels) which would require Zoning Board of Review variance approval to be developed and those derived from subdivision of larger parcels.

In more recent years the number of potential new homes has been reduced by the purchase and/or protection through conservation easements of two of the larger remaining undeveloped parcels and an unknown number of smaller parcels. In 2006 the Prudence Conservancy acquired a conservation easement on Blount land and in 2010 the State of Rhode Island purchased the Ballard property which together reduced the number of potential new lots by subdivision by as much as 160. However, the possibility of doubling the number of homes on Prudence Island still exists.

Professional Assistance

On two occasions in 2006 the PIGWTF requested assistance from agencies and individuals with the appropriate professional training and experience to provide a more thorough interpretation of the totality of past study results (some of which were in disagreement) and future direction for PIGWTF efforts. The first meeting was with USGS staff and the second with representatives of various state agencies including appropriate divisions of Rhode Island Department of Environmental Management (RI DEM). In both instances, a synthesis of results of past studies and an overview of island and Mill Creek watershed characteristics was presented.

When Dr. Urish was asked in an interview what additional studies or modeling would be necessary in order to fully understand the flow and dynamics of groundwater on Prudence Island, he indicated that the

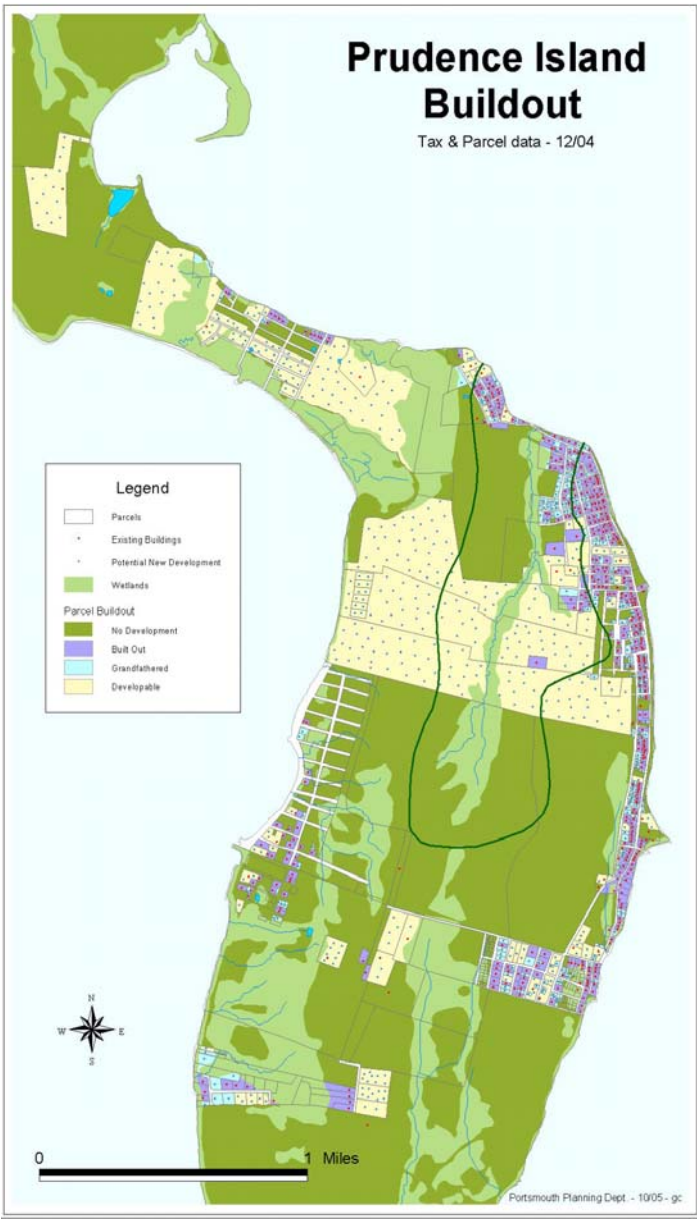

Figure 2: Graphic representation component of the Prudence Island build-out analysis conducted by the Portsmouth Planning Department in 2005.

Table 1: Estimated number of buildable lots by zoning district.

Zoning District	*Use*	*Required minimum lot size in acres*	*Number of grandfathered parcels*	*Number of lots from subdividing*
R-20	Res.	0.46	209	140
R-60	Res.	1.38	12	268
Total			**221**	**408**

scope of the study required would be huge. In fact, he felt that the only entity capable of a study on this scale would be the USGS. As a consequence, the PIGWTF arranged to discuss the possibility of a study of the island's groundwater resource with a USGS representative. We were informed that the effort would require data collection over a period of years to capture seasonal and annual variability and would potentially include measures of surface water levels, groundwater levels, stream flow, pumping rates, and precipitation prior to any modeling of the groundwater resource. While seemingly willing to undertake this project and recognizing the legitimate need, the USGS does not have internal funding for studies of this type and costs associated with a multi-year study would need to be acquired externally. A loose estimate of cost was suggested to range from $200,000 to $250,000 and funds for the study were simply not available. The USGS representative did suggest that the PIGWTF begin a monthly monitoring program which, in the event that funds were available at a later date, would reduce the scope (and associated costs) of a future study.

The PIGWTF, having essentially exhausted their limited resources to address concerns about the Prudence Island groundwater resource, called a meeting to seek additional input and guidance from experts. Specific topics to be addressed during the roundtable discussion included: the adequacy of the existing research, additional research that may be necessary, strategies for conducting additional research, and mechanisms to protect the groundwater resource until additional research is completed. The agencies represented at the meeting and recommendations for next steps are listed below.

Discussion Participants

- RI DEM, Office of Sustainable Watersheds
- RI DEM, Office of Water Resources
- RI Department of Health, Office of Drinking Water Quality
- RI Coastal Resources Management Council
- RI Division of Planning
- RI Water Resources Board
- U.S. Geological Survey
- Atlantic States Rural Water and Wastewater Association
- URI, Department of Geosciences
- Coalition for Water Security
- Narragansett Bay National Estuarine Research Reserve
- Prudence Island Water District
- Prudence Conservancy

Roundtable Discussion Recommendations

- Evaluate water-bearing fracture zones
- Monitor stream flow and groundwater levels
- Map chloride levels in areas serving private wells
- Increase oversight of well drilling
- Consider adopting a "merger clause" for undersized lots
- Implement a Resource Protection Overlay District
- Pursue EPA designation as a Sole Source Aquifer
- Adopt a moratorium on development until water issues are addressed
- Install residential water meters
- Educate stakeholders

Significantly more detail was contained in the actual discussion however the basic consensus was that we did in fact need additional information to inform decisions about the resource and to determine how best to address concerns about continued development. Well drilling practices on the island and uncertainties regarding the size/extent of the aquifer garnered the greatest amount of discussion. Specifically, although the moratorium remains in place to restrict the number of PIWD service connections, new customers continue to be added as previous customers install wells due to objections over water quality and/or cost and drop their service connections resulting in an increase in overall water use. Typically the installation of wells for pre-existing homes occurs without benefit of site inspection and engineering reports on parcels too small to meet offset requirements for both well and septic systems. This increases the potential for contamination of the groundwater resource. Unfortunately, the number of well completion reports (which are required to be filed with the Department of Health yet none were available since 2000) did not reflect the actual number of newly installed wells and no consensus was reached regarding how to improve oversight of well installations. An associated discussion related to how the addition of wells both within and outside the Mill Creek watershed would impact the availability of groundwater at the community wellheads. For instance, will the placement of deep wells proximate to the shore increase the potential for saltwater intrusion? Does the island have a single aquifer from which all wells are withdrawing water or, if multiple, are they connected via bedrock fractures either near the ground surface or deep underground? Through the discussion it became evident that we simply do not yet know enough about the aquifer and its storage capacity to make informed decisions regarding the influence of increased development demands. It was recommended that we take steps to protect this resource until such time as these remaining questions were adequately answered.

Community Workshops / Public Presentations

In an effort to meet the roundtable participants' recommendation to educate stakeholders, the PIGWTF sponsored a series of public events. The coordination of individual community workshops and public presentations was primarily the responsibility of the NBNERR Coastal Training Program (NBNERR-CTP) coordinator. The NBNERR-CTP coordinator assisted the PIGWTF in identifying appropriate speakers and forums for reporting concerns pertaining to the Island's groundwater resource as well as current PIGWTF activities to targeted audiences. In total the PIGWTF held two community workshops and a public presentation.

The PIGWTF presented limited review materials at a Town Council meeting held on Prudence Island in August of 2006 and requested that the Council sponsor a public workshop the following summer. While Town Council members expressed an interest in the groundwater issue and proposed workshop at that time they were later unwilling to serve as workshop sponsors due to fears that it would be perceived to be attempting to restrict development (as opposed to providing resource protection). NBNERR also refused to sponsor the workshop for the same reasons.

Sponsors for a community workshop held in June 2007 included the Prudence Conservancy, the Prudence Island Utilities Corporation, and the Prudence Island Water District. The workshop was promoted through a Sakonnet Times newspaper article, signage, and through the distribution of postcards at the ferry landing announcing the event (Figure 3) and was well attended. The overall intent of the workshop was to provide a forum for educating the public regarding groundwater concerns that had been recently acknowledged throughout the state and locally. Guest speakers presented on the following topics:

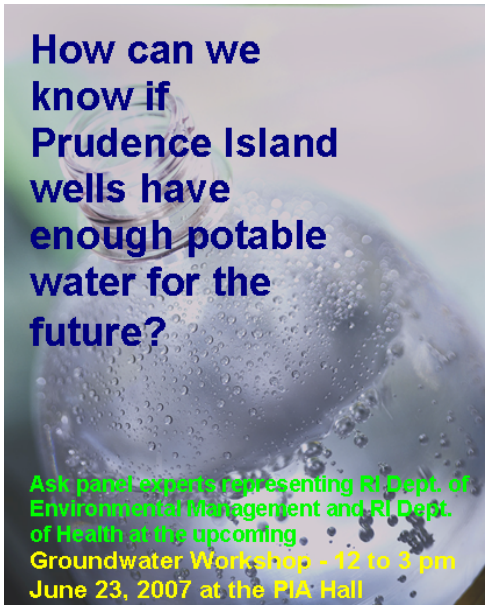

Figure 3: An example from a series of postcards distributed to announce the public workshop.

- The role of the Rhode Island Water Resources Board in the state and a description of how Prudence Island fits into the overall picture
- An overview of basic island hydrology
- Evidence from past studies and recent resource protection recommendations
- Upcoming Prudence Island groundwater research activities
- Rainwater harvesting

Following the presentations, participants had an opportunity to address questions to a panel of experts representing the following agencies: Coalition for Water Security, RI Water Resources Board, URI Geosciences Department, RI Division of Planning, RI Department of Health, RIDEM Office of Water Resources, and the US Geological Survey. See Appendix 2 for copies of workshop hand-out materials.

A number of island residents who attended the first workshop indicated a desire to learn more about what they could do as homeowners to better protect the groundwater resource. As a result, the NBNERR-CTP Coordinator organized a second community workshop held in May 2008 titled 'Prudence Island Homeowners' Sustainable Landscaping and Water Conservation Workshop'. This workshop was not as well attended however a series of guest speakers provided some excellent information regarding water conservation strategies in and around the home. See Appendix 3 for copies of workshop hand-out materials.

CICEET Proposal

A number of individuals involved with the PIGWTF submitted a proposal for funding in 2007/08 to the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) titled 'The development of a three-dimensional bedrock fracture map for Prudence Island, Rhode Island to identify potential contaminant pathways into Narragansett Bay through submarine groundwater discharge'. Authors included representatives from NBNERR, PIWD, URI, and USGS. While the proposal itself was not intended for public distribution, the proposed project intent was to generate a three-dimensional map of the fractured bedrock aquifer (using electromagnetic and thermal infrared imagery) and freshwater submarine discharge in the adjacent coastal area (using thermal infrared imagery and radon detection [if found suitable to this location]) to allow for the identification of potential contaminant pathways. If any pathways were found to exist in areas where contaminant sources are in close proximity to bedrock fractures then random water samples at the associated submarine groundwater discharge sites would be tested for contaminants. The presence/absence of contaminants and pathways distances would provide valuable insight as to the transport of contaminants into coastal areas via submarine discharge through bedrock fractures. Unfortunately the project was not funded because at least one product (the map of bedrock fractures) would have been a tremendous PIWD resource for sighting new wells, evaluating aquifer storage capacity, etc.

NBNERR Needs Assessment / Survey

As a component of its management plan development, NBNERR conducted a community needs assessment and survey of island residents in 2006 to determine how best to serve the island community as well as capture priority interests and characteristics of that community. The PIGWTF was invited to

contribute questions regarding water use and development potential (i.e. plans for upgrades to existing homes including conversion to year-round use, building on vacant lots, sale/transfer of properties, etc.). The survey was intended to include all property owners (n=441) as possible respondents however, for a variety of reasons, only 169 surveys were completed so the responses may or may not be representative of the Island population as a whole. Select questions and a subset of survey inferences are provided below. See Appendix 4 for additional detail. A complete survey report is available in Appendix D of the Narragansett Bay Research Reserve 2010-2015 Management Plan (available: http://www.nbnerr.org/Content/NBNERR_MngtPlan2010.pdf).

Select Survey Questions:

- In an average year, during which months is your residence occupied? [Response options: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec]
- If you are able to within the next five years, will you increase the amount of time you live on the island? [Response options: No, Yes, Maybe, Already live there year round, Don't know]
- What is the water source for your property? [Response options: Prudence Utility Corporation, Prudence Park Water Association, Private well, There is no water source on the property, Don't know]
- Does the quality of your water influence how much you use? [Response options: No, Yes, Don't know]
- Does anyone regularly drink tap water on your property? [Response options: Drink the water on property, Bottled water only, Neither one, Both, Don't know]
- Within the last 5 years, which of these changes have you made to your residence(s) on the Island? [Response options (Y/N) to each of the following: Increase the amount of space, Winterized it, Put it up for sale, Transferred it to a family member, Put in a new well, Upgraded the septic system]
- If you are able to within the next 5 years, which of these decisions will you make about your residence(s) on the island? [Response options (Y/N) to each of the following: Increase the amount of space, Winterize it, Put it up for sale, Transfer it to a family member, Put in a new well, Upgrade the septic system]

Select Phone Survey Responses

- 44% report that they would prefer to increase the amount of time that they live on the island (Note: More than half of respondents indicated that they already spend time on Prudence from April to November)
- 43% indicated that they limit overall water use due to water quality concerns
- 43% drink Island water
- 28% have winterized their homes in the past 5 years (13% plan to winterize their homes in the next five years)
- 9% installed new wells in the past 5 years (2% plan to install a new well in the next five years)

Although not comprehensive, the phone survey did confirm the trend from summer seasonal to more full-time use indicating a greater water use demand than in previous decades. It also confirmed that water quality concerns (real or perceived) do influence use.

Recent Studies

Dr. Veeger, Chair of the Geosciences Department at the University of Rhode Island, conducted a study in 2007 to determine connectivity of the island aquifer and surface waters with assistance from the

PIGWTF. In addition to identifying a graduate student to assist with this research, Dr. Veeger also identified an appropriate funding source to make this study feasible. Island residents volunteered to contribute well and stream water samples which were tested for mineral content indicative of deep draft, 'fossil' waters. A systematic evaluation of island-wide water quality variations would help to identify:

- zones where salt-water intrusion is occurring or likely
- impacts of current land use on water quality
- zones that are hydrologically connected to surface water/wetlands
- relative ages of water based on the degree of chemical interaction with bedrock materials

The results of this study have not yet been made available pending publication.

Monitoring

Monthly monitoring of groundwater levels and stream flow was undertaken at the recommendation of USGS staff to establish baseline data for developing models of the Island's groundwater resource. In particular, efforts to determine aquifer storage capacity and recharge potential require repeat measures of precipitation (inputs), stream flow (outputs), and groundwater levels (recharge/storage). Variations in all parameters are expected to occur both seasonally and annually and monitoring over multiple years is necessary to capture these variations. Annual variability is directly correlated with precipitation levels. Inter-annual (seasonal) fluctuations are driven by variation in levels of evaporation, transpiration, and demands for human use. Monitoring protocols and data sheets are available in Appendices 5 and 6, respectively.

Monitoring locations were selected (to the extent possible) to provide the greatest possible spread across the landscape and to occur within multiple watersheds (Figure 4). Site selection also took into account available access and property owner permission. Initial monitoring sites represented twelve groundwater wells and eight stream locations. A data record for one well located on the 'neck' of the Island (not shown on Figure 4) was maintained or a period of eighteen months before being dropped. In addition to being shallow and tidally influenced this well had high manganese content which fouled monitoring equipment. Additional groundwater level monitoring occurs at PIWD supply wells (shown on Figure 4) and the data record is maintained separately by that agency. One stream monitoring station (depicted on Figure 4) has also been dropped due to issues with the adjacent culvert which commonly impeded water flow.

Monthly monitoring of groundwater levels and stream flow has been ongoing since June 2006 and January 2007, respectively. While monitoring to date has been conducted with volunteer effort, the PIWD will assume responsibility for monitoring field work as soon as training and the transfer of equipment has been arranged. NBNERR will continue to maintain the data set and keep the PIWD updated on the current water level stage (Appendix 8).

<u>Groundwater level</u>

Changes in groundwater levels in wells reflect changes in aquifer storage. If recharge (from precipitation and surface water infiltration) exceeds discharge (from well withdrawals, evapotranspiration, and natural flow to streams) groundwater levels go up. Conversely groundwater levels go down when discharge exceeds recharge. Water levels typically display a seasonal pattern with higher levels in the winter and spring due to greater recharge and lower levels in the summer and fall due to less recharge,

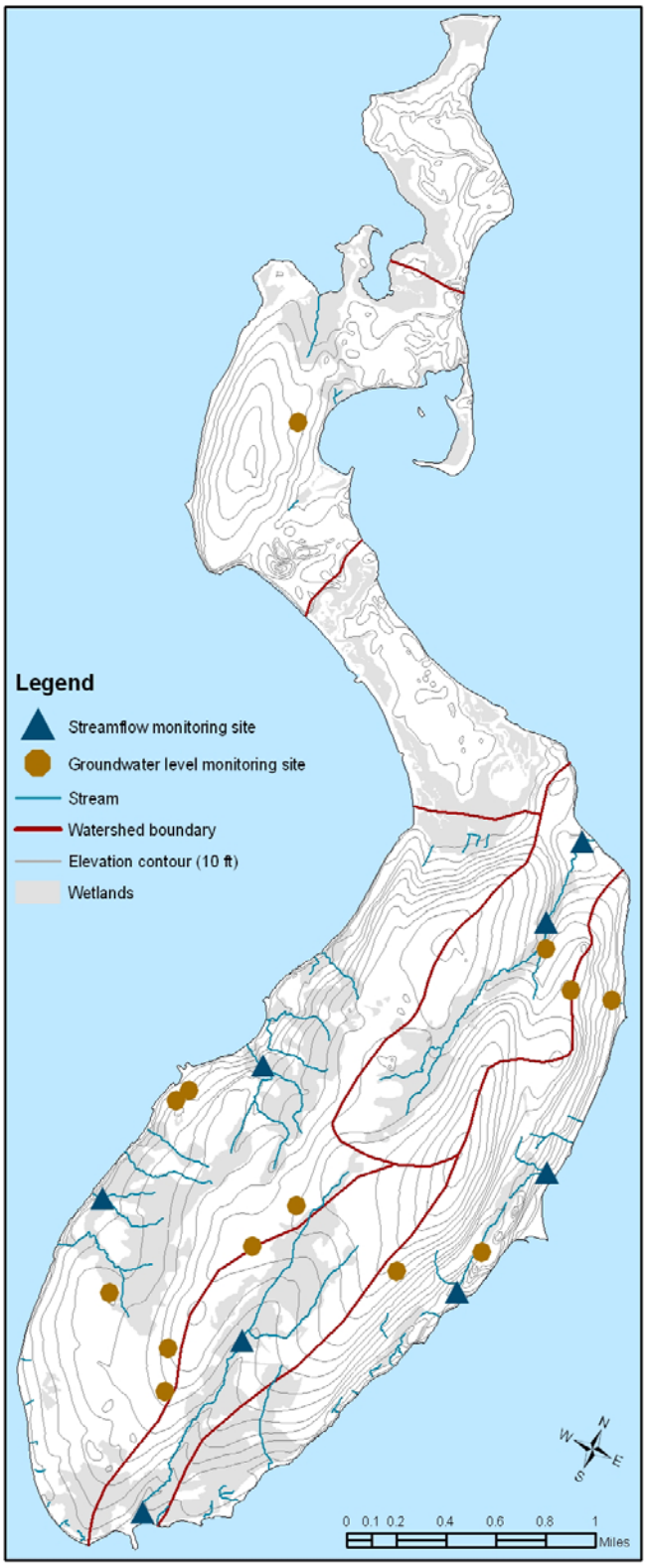

Figure 4: Initial monitoring sites.

increased pumping, and greater evapotranspiration (Leeth and Clarke, 2003). Groundwater level data collected in island wells displays this cyclic pattern (Figure 5).

Annual variations in groundwater levels are almost entirely driven by the timing and amount of precipitation. As can be seen in Figure 5 both 2007 and 2010 represent years of moderate drought while 2008 experienced above-average rainfall. In order to capture the full range of variability both within and between years it is necessary to continue monitoring for an extended period of time. While seasonal patterns are already beginning to be captured in the data set and we have experienced a moderate range of precipitation conditions it is not yet possible to characterize groundwater levels relative to 'normal', although initial estimations are possible.

Groundwater level data has been used by the PIWD since 2009 to determine conservation water level stage and to implement appropriate water use restrictions. Stage computations to date are provided in Appendix 7. Following a general consideration of mechanisms applied for this purpose elsewhere, the final selection was based on one, two, and three month running averages computed for the period of record for each of two locations (the Pier Road and Broadway monitoring wells). A change in stage designation also requires that precipitation is less than 75% of normal for each individual month. Specifically, stage level is computed as follows:

Stage 1 Monthly record is less than 10% greater than the 2 month average
Stage 2 Monthly record is more than 10% greater than 2 month average
Stage 3 Monthly record is more than 15% greater than 2 month average and more than 10% greater than 3 month average
Stage 4 Monthly record is more than 15% greater than 2 month average and more than 20% greater than 1 month average

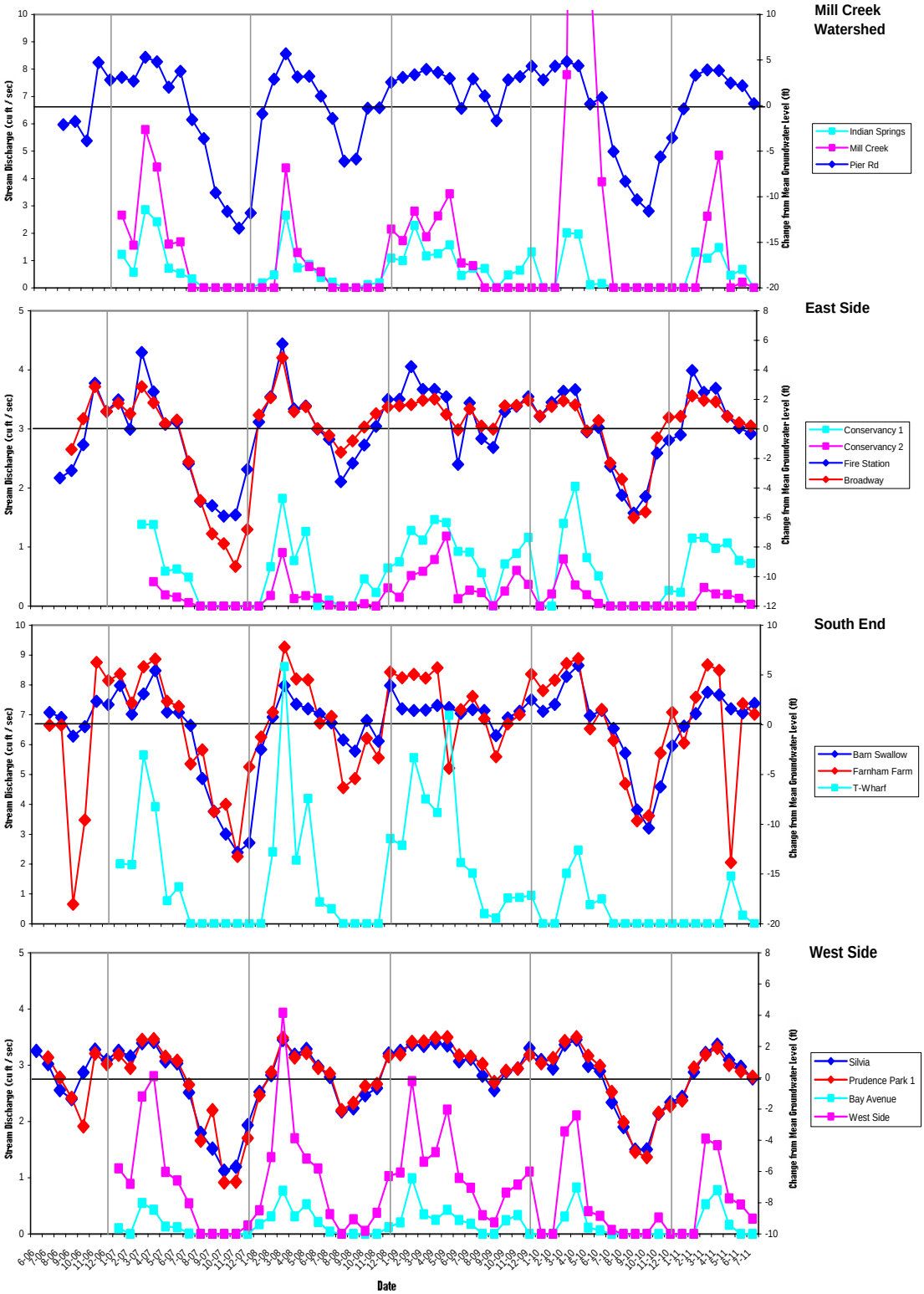

Figure 5: Monthly data records for representative streams and wells in each of four general drainage areas. Higher water levels are typically present in winter and spring then drop during the summer and autumn months. Wells are indicated by diamonds and stream monitoring sites are represented as squares.

Stream Flow

The volume of water flowing in streams represents that portion of precipitation which does not have an opportunity to infiltrate into the ground as well as surface water infiltration from groundwater. In winter and spring when the ground is saturated and the aquifer is recharged to its highest level, stream flow (which is the volume of water multiplied by its velocity) is at its highest. From late spring through late autumn stream flow is reduced due to generally lower rainfall and increased evaporation and plant transpiration (together called evapotranspiration). Like the groundwater level data, stream flow data displays this expected seasonal pattern (Figure 5).

Not only the amount, but also the timing of precipitation events will influence the amount and duration of water flow in streams. For instance, a heavy rainfall event such as the 'historic' March 2010 storm which occurred after the aquifer had reached its maximum storage capacity and the soil surface was fully saturated resulted in record flooding in the state. [Note that stream flow levels recorded in Mill Creek two days after the storm were well outside the normal range for this monitoring station (Figure 5)]. A similar rainfall event occurring later in the year would have resulted in greater groundwater recharge and correspondingly less stream flow. Capturing the full range of seasonal and annual variation possible as well as modeling the relationship to precipitation events will require monitoring of stream flow over multiple years.

Monitoring of stream flow is conducted in accordance with USGS established protocol for narrow streams less than 2.5 feet in depth (Appendix 5). Profiles depicting the streambed from a static reference line (Figure 6) are determined at three inch intervals between permanent stakes (or existing stable man-made features) in order to compute stream section volumes at any recorded water level height (or stream stage). Periodically, these profiles need to be re-measured to account for changes in the streambed surface; particularly following intense storm events with periods of heavy rainfall.

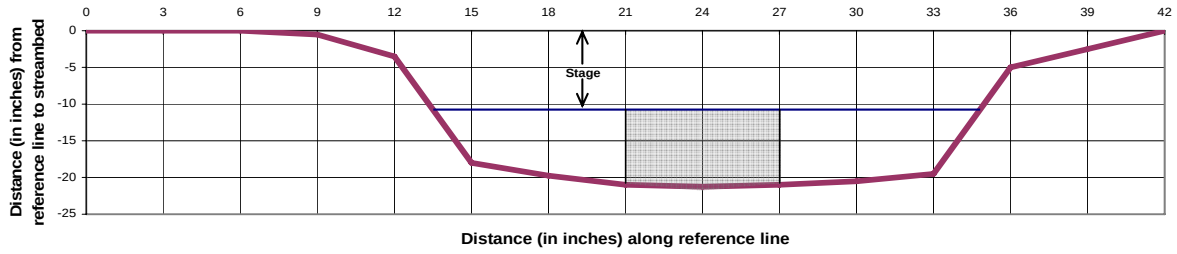

Figure 6: Streambed profile at T-Wharf stream flow monitoring site with reference stream stage and volume of individual stream section depicted in gray.

Discussion

The PIGWTF was an active body over a period of years and contributed a great deal to the general knowledge about the groundwater resource on Prudence Island. Unfortunately, although the task force is no longer a functioning body, there is still a need to continue to press for further studies so that this resource can be managed effectively. The greatest unknowns remain the location and extent of the underlying aquifer and the extent to which additional demand could compromise this limited resource.

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Appendix 1: Executive Summaries from select groundwater studies

GZA Environmental. 1999. Geohydrologic Study for Prudence Island, Portsmouth, RI for Division of Public Utilities and Carriers, File No. 32230.00.

Executive Summary

Based on pumping records at the end of the summer of 1999, the existing four wells have a combined short-term capacity of approximately 49 gallons per minute (gpm) or approximately 71,000 gallons per day (gpd). The storage capacity of the system was 24,000 gallons and we understand that the system storage is to be increased to at least 100,000 gallons. With the existing storage capacity, however, the estimated peak-day supply was approximately 95,000 gpd.

The peak-day demand in 1999 was 87,500 gallons (on June 6); and we estimate that without water restrictions, and if the supply were available, would be on the order of 130,000 gpd. Consequently, the existing system does not, at all times, meet the needs of the 325 residences that are currently connected to the system.

Conversely, the system has more than sufficient capacity to meet the average daily demand (based on historical records) of approximately 36,000 gpd or 25 gpm, and marginal capacity to meet the average daily summer demand of 53,000 gpd or 37 gpm. (Note the demand of 53,000 gpd is based on pumping records from five summers and may be artificially low because of system capacity and water restrictions).

Based on available data, we believe that the short-term sustainable capacity of the system is limited by pump capacity, storage, and perhaps saltwater intrusion. Further, with careful monitoring, we believe that seasonally, the short duration pumping from well R-4 can be increased from 28 gpm to on the order of 40 gpm, by increasing the capacity and lowering the depth of the pump. That is, we believe well R-4 has sufficient capacity to yield 40 gpm and the likely-hood of saltwater intrusion, as a result of short-term duration pumping rates of less than about 40 gpm, is small. Consequently, by adding the proposed additional storage and with monitoring, we believe that the distribution system can be expanded to accommodate a limited number of additional connections. These opinions are based on limited data and rely upon judgment. The actual short-term sustainable capacity (days) of the four wells may be more or less than our estimate of 60 gpm or 86,000 gpd.

We emphasize, however, that demand can exceed the capacity of the four wells and that operation of the system should include the monitoring of water levels and measurements of salinity in each of the wells (See Section 5.00). We also emphasize that additional storage is needed to meet peak-day demand and that additional storage would allow for more efficient long-term use of the wells.

This summary provides an overview of our findings. It is important that the report be read in its entirety to understand how we reached these opinions and the inherent uncertainties associated with them.

Urish, D. W. 2004. Evaluation of Ground Water Level and Pumping Trends, Prudence Island, Rhode Island. Prudence Island Utilities Corporation.

Executive Summary

Pursuant to the request of the Prudence Island Utility Corporation an evaluation of ground water level and pumping information/data for the period 1997-2004 was accomplished relative to concerns over declining water levels in a key monitoring well.

The trend of declining water levels in the monitoring well (RW-3) since pumping began in the deep bedrock wells constructed in 1994 is cause for concern. While RW-3 is 476 feet south of pumping wells RW-1 and RW-4, it is in the same watershed area and thus is indicative of conditions at the pumping wells. This relationship was positively established during pumping tests by D.L.Maher Company in 1995. The water level decline shows that over the long term more water is coming from storage than is being replenished by ground water recharge. While it may level off as more groundwater recharge area contributes and if pumping rates do not increase, there is a potential and concern for salt water intrusion into the deep bedrock wells.

It is to be noted that the fractured bedrock hydrogeology of Prudence Island is poorly known. Although the wells appear to be in a well-defined relatively permeable fracture zone as determined by D.L. Maher in 1995 prior to the drilling of the three deep bedrock wells, the continuity of intercepted fractures and recharge areas are not known. It has been established however, from water level monitoring that the fractures respond to tidal fluctuations and are therefore connected with the salt water of Narragansett Bay. It is to be noted that approximately 3/4 of the contributing watershed is to the south of the pumping wells, while 1/4 is to the north in direct connection with the salt water boundary. Hence there appears to be a significant possibility of salt water intrusion through bedrock fractures from the north before the entire aquifer water producing potential can be realized. This concern is reinforced by the recognition that the fracture zones identified by D.L. Maher (1993) extend in a concentrated pattern north along Mill Creek directly to the shoreline.

The annual pumping quantity of 10 to 12 mg is within the estimated annual amount of 15.7 mg available in Region IV (Urish, 1992). However it is to be noted that the ability to actually obtain this amount depends on the well locations and design; deep bedrock wells greatly increase the possibility of salt water intrusion in an island environment. Pumping typically lowers the water table until new aquifer equilibrium is reached. This has not yet been achieved at the pumping wells constructed in 1994, even though precipitation has generally increased during this six year evaluation period.

At this time there is no indication of salt water intrusion. The salinity of water as measured in terms of electrical conductivity has changed little from initial well development. At that time the electrical conductivity was reported 200 to 220 micro-mhos in wells RW-1 and RW-4. It is currently reported as 180 to 210 micro-mhos. These values are comparable to values for good quality groundwater on the mainland.

The water level in the groundwater recharge area for the three deep wells constructed in 1994, located as shown in Figure 1, has been declining steadily since pumping began in 1995. This decline is reflected both in summer low and the spring high water levels. Based on water level records in monitor well RW-3 for a six year period during 1997-2004 the spring water levels ranged from a high of -17 ft. to a low of -20 ft., with an average decline of about 0.5 ft/year.

The decline of the water table is a natural response to pumping. Typically the water table declines in an area of pumping influence until a balance is reached where the recharge in that area is equal to the withdrawal, or until an impermeable (or salt water) boundary is reached, in which case an equilibrium may never be reached. The wells are located in the central area of the island, Region IV, with watershed boundaries identified as topographic highs. It should be recognized, however, that the contributing fractures and their flow paths are complex and poorly known. It is likely that the bedrock fractures extend beyond the defined watershed with an ultimate connection with salt water.

The Prudence Island system continues to be a marginal system with no backup if one of the wells goes bad. Since the two main bedrock wells are so near each other they do not represent backup to each other, except for pump outages. The water quality and quantity of the two wells is linked.

The following is recommended:

A. Continue weekly water level monitoring in RW-4, and in RW-3 to the extent possible.
B. Continue measuring raw water from both wells for electrical conductivity as an indicator of salinity, with concurrent plotting for detecting trends. If the pumped water starts to show an increased salt content (increased electrical conductivity) then reduced pumping is absolutely essential.
C. Pursue the construction of an additional backup well outside of Region IV. The best candidate is the former Navy site at the south end of the island at the fracture zone confluence identified by D.L. Maher in 1995.
D. Keep strong water use controls on summer pumping, especially during dry summers, and when reduced water table highs in the spring are experienced, such as occurred in 2004 because of the major leak. In this regard it might be worth reconsidering the water rate cost structure with metering as a means of effecting water conservation.
E. Be especially vigilante for leaks, which put an extreme strain on the system. Metering would also provide a means of early leak detection in both user locations and within the system.

Appendix 2: Handout materials from workshop held on June 23, 2007

Prudence Island Groundwater Workshop

June 23, 2007, 12:00 pm – 3:00 pm
Prudence Improvement Association Community Hall

AGENDA

12:00 Introduction and Welcome
Harry Sterling, Prudence Island Groundwater Task Force

12:10 The role of the RI Water Resources Board and how Prudence Island Fits Into the Overall Picture
Kathy Crawley, Staff Director, Water Allocation Program, RI Water Resources Board

12:20 Overview of Basic Island Hydrology
Emily Wild, Hydrologist, U.S. Geological Survey
Rob Breault, Hydrologist and Deputy Director, U.S. Geological Survey

1:00 Break

1:10 Prudence Island Groundwater Issues
Robin Weber, Prudence Island Groundwater Task Force

1:50 Upcoming Prudence Island Groundwater Research Activities
Anne Veeger, Chair, Geosciences Department, University of Rhode Island

2:00 Break

2:10 Panel Discussion
Moderator: Bob Marshall, Prudence Island Groundwater Task Force

3:00 Adjourn

Prudence Conservancy

Prudence **I**sland
Utility **C**orp.

PRUDENCE ISLAND WATER DISTRICT

Workshop Panel Participants

Clay Commons
Environmental Scientist, Office of Drinking Water Quality, RI Department of Health

The R.I. Department of Health has authority for the enforcement of the Safe Drinking Water Act. They are also responsible for monitoring the state's surface and ground water drinking sources and public water systems, new source locations, and new storage treatment or pumping facilities at existing public water systems.

Kathleen Crawley
Staff Director, Water Allocation Program, RI Water Resources Board

The R.I. Water Resources Board is an executive board in state government created to regulate the proper development, protection, conservation, and use of water resources of the state. They were granted sole authority by the R.I. General Assembly to devise a fair and equitable allocation of water resources among users and uses.

Nancy Hess
Principal Environmental Planner, Division of Planning, RI Department of Administration

The R.I. Statewide Planning Office oversees the implementation of the State Guide Plan, which outlines the water planning policies in the state. The State Guide Plan contains three elements that deal with water supply: Element 721, Water Supply Policies; Element 722, Water Supply Plan; and Element 723, Water Emergency Response Plan.

Ernie Panciera
Supervising Environmental Scientist, Office of Water Resources, RI Department of Environmental Management

The primary responsibility of the Office of Water Resources is to control and abate sources of pollution to the state's groundwater and surface water. Their mission is to insure that rivers, lakes, and coastal waters will support healthy communities of fish, plants, and other aquatic life, and will support uses such as fishing, swimming, and drinking water quality, and to insure that groundwater is protected for drinking water and other beneficial uses.

Dr. Anne Veeger
Dept. Chair, University of Rhode Island Geosciences Department

Geosciences include all of the sciences, such as geology or geochemistry, that deal with the earth. Dr. Veeger's specific research interests include hydrogeology, isotope hydrology, aqueous geochemistry, and numerical modeling of ground-water flow.

Emily Wild, Hydrologist, U.S. Geological Survey
Rob Breault, Hydrologist and Deputy Director, U.S. Geological Survey

The U.S. Geological Survey plays a large role in the development of scientific background information for use in devising and implementing water supply management initiatives. They conduct scientific research on sources, availability, and hydrologic functions of ground and surface water resources.

Resources

(Note: the PowerPoint presentations will be available at www.nbnerr.org shortly after the workshop)

Websites

General Assembly
Legislation related to water use, supply and distribution in Rhode Island (H 6151, S 1098, others)
http://www.rilin.state.ri.us/Genmenu/#

Special House Commission to Study Water Use and Distribution
http://www.rilin.state.ri.us/wateruse/

Coalition for Water Security
http://www.coalitionforwatersecurity.org/

RI Department of Environmental Management
Groundwater/Wellhead Protection Program
http://www.dem.ri.gov/programs/benviron/water/quality/prot/index.htm

Environmental Protection Agency
The Office of Ground Water and Drinking Water
http://www.epa.gov/safewater/

Water Sense: Efficiency Made Easy
http://www.epa.gov/watersense/

U.S. Geological Survey
Groundwater Resources Program
http://water.usgs.gov/ogw/gwrp/

National Water Use Program
http://water.usgs.gov/watuse/

RI Department of Health Office of Drinking Water Quality
http://www.health.ri.gov/environment/dwq/index.php

Rhode Island Water Resources Board
http://www.wrb.state.ri.us/

University of Rhode Island Department of Geosciences
http://www.uri.edu/cels/geo/

Rhode Island Statewide Planning Program
http://www.planning.state.ri.us/

Prudence Island Water District
http://www.pih2o.org

Reports and Other Documents

Senate Committee on Environment and Agriculture and Senate Committee on Government Oversight "Water for Tomorrow: From Planning to Implementation Findings and Recommendations from the Joint Hearings on Water Related Issues" (June 6, 2007)
http://www.rilin.state.ri.us/Documents/SWaterReport.pdf

"A Sustainable Approach to Water Supply and Use in Rhode Island" (April 2006)
http://www.ripolicy.org/watersecurity/Sustainable%20Approach%20to%20Water%20-Report.pdf

Article in Providence Business News by Coalition for Water Security members Beth Ashman Collins and Cynthia Giles: "Healthy Water Supply Promotes Economic Health"
http://www.pbn.com/stories/25767.html

Prudence Island Source Water Assessment (2003)
http://www.health.ri.gov/environment/dwq/ccr/prudence/prudence.pdf

State Guide Plan Element 721: Water Supply Policies for Rhode Island
http://www.planning.state.ri.us/landuse/pdf/721.pdf

Prudence Island Groundwater Workshop

Saturday, June 23, 2007, 12:00 pm – 3:00 pm
Prudence Improvement Association Hall
Prudence Island, RI 02872

EVALUATION

1. Affiliation (please check all that apply)

___ Prudence Island resident

___ town council	___ land trust	___ federal government
___ planning dept.	___ watershed council	___ business/private consultant
___ planning board	___ conservation commission	
___ zoning board	___ university/college	___ other
___ other municipal staff	___ state government	_____

2. Using a scale of 1-5, what was your understanding or knowledge of this issue before and after attending the workshop?

Before

1 = none 2 = below average 3 = average 4 = above average 5 = high

After

1 = none 2 = below average 3 = average 4 = above average 5 = high

3. Do you intend to apply the knowledge you have acquired today in your home, work and/or decision-making?
___Yes ___ No Specifically how?

4. Did you hear any new perspectives (i.e. different ways of thinking about this topic) from the presenter or others that you may apply in your home, work and/or decision-making?
___Yes ___ No In what way?

5. How satisfied were you with the overall content of the information provided at this workshop? ("1" = not satisfied; "3" = satisfied; "5" = very highly satisfied)

1 2 3 4 5 →

6. How satisfied were you with the overall delivery of the information provided at this workshop? ("1" = not satisfied; "3" = satisfied; "5" = very highly satisfied)

1 2 3 4 5 →

7. Do you think that your ability to access resources relevant to the use / management of water in your home, work, or decision-making will increase as a result of attending this workshop?
___Yes ___ No If not, how can we improve in this area?

8. Do you intend to discuss the issues addressed today with others (e.g. family, friends, neighbors, colleagues) as a result of attending this workshop?
____Yes ____ No

9. Please list any other topics you would like an opportunity to learn more about.

10. Any additional comments?

OPTIONAL (*All evaluation responses are confidential*)

Name: _____
Affiliation: _____
Address: _____
E-mail: _____
Phone: _____

THANK YOU FOR YOUR TIME IN COMPLETING THIS EVALUATION

Appendix 3: Handout materials from workshop held on May 17, 2008

Prudence Island Homeowners' Sustainable Landscaping and Water Conservation Workshop

Saturday, May 17, 2008, 12:00 pm – 2:30 pm
Hope Brown Center
Prudence Island, RI

AGENDA

12:00 Introduction and Welcome
Jennifer West, Coastal Training Program Coordinator, Narragansett Bay Research Reserve

12:05 Water in the News: Crisis vs. Conservation at the Local, State and National Levels
Jennifer West

12:20 Sustainable Landscaping for Water Conservation
Rosanne Sherry, State Master Gardener Program Coordinator

12:50 Composting and Yard Waste Management
James Crowey, Master Composter and Recycler

1:20 Break

1:30 Rain Barrels and other Backyard Water-saving Tools and Techniques
Beverly O'Keefe (aka "The Water Lady"!), RI Water Resources Board and URI Extension Master Gardener

2:00 Composting Toilets: A Great Way to Address Septic System Concerns!
Robin Weber, Natural Resources/GIS Specialist, Narragansett Bay Research Reserve

2:15 Wrap-Up and Adjourn

Homeowners' Sustainable Landscaping and Water Conservation Workshop
Saturday, May 17, 2008, 12:00 pm – 2:30 pm
Hope Brown Center
Prudence Island, RI 02872

EVALUATION

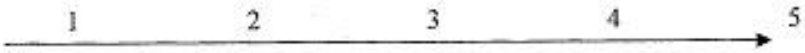
1. Did your understanding or knowledge of this issue increase as a result of attending this workshop?
____Yes ____No

2. Do you intend to apply the knowledge you have acquired today in your home, work and/or decision-making?
____Yes ____ No

3. Did you hear any new perspectives (i.e. different ways of thinking about this topic) from the presenter or others that you may apply in your home, work and/or decision-making?
____Yes ____ No

4. How satisfied were you with the overall content of the information provided at this workshop?
("1" = not satisfied; "3" = satisfied; "5" = very highly satisfied)

5. How satisfied were you with the overall delivery of the information provided at this workshop?
("1" = not satisfied; "3" = satisfied; "5" = very highly satisfied)



6. Do you think that your ability to access resources relevant to the use / management of water in your home, work, or decision-making will increase as a result of attending this workshop?
____Yes ____ No

7. Please list any other topics you would like an opportunity to learn more about.

8. Any additional comments?

Appendix 4: NBNERR Survey Results (a White Paper report authored by Dr. Kenneth Raposa)

Some Conclusions: NBNERR Survey

Introduction

NBNERR conducted a survey of Islander's attitudes about the research reserve in early fall of 2006. At the request of the Island Water Issues Task Force, they included a few questions about development: actual and planned. This report consists of a very small part of the data from the survey, and NBNERR will be posting the entire survey report on their website. This summary is unofficial; it may not represent the conclusions of NBNERR staff. The numbers reported, however, are directly derived from the survey results.

This survey was not intended to be a sample survey; the whole universe of 441 property owners were included. However, only 263 phone numbers were found, and 169 surveys completed.

Survey Completion Percentages

Survey Completion Categories	N	% all property owners	% owners with available phone numbers
All property owners	414	100.0	
Phone numbers not available	151	36.5	
Phone numbers available	263	63.5	100.0
Listed property owner deceased	3	.7	1.1
Unable to reach	43	10.4	16.3
Declined	48	11.6	18.3
Completed survey	169	40.8	64.3

When a sample is drawn for a survey, typically every person in the universe has an equal probability of being included. For this type of survey (a random sample survey) well established statistical techniques exist to determine how reliably the answers can be extrapolated to the entire universe. Instead of a random sample survey, this survey was intended to include the whole universe of possible respondents, avoiding the necessity of extrapolation. If all persons had responded, the answers would have reliably represented all property owners. For several reasons, only 41% of the Island property owners completed a survey and the 37% of property owners without available phone numbers had no opportunity to complete the survey. The answers, thus, do represent a large group of property owners. They may or may not represent all property owners.

Characteristics of Respondents

Two thirds of the respondents have owned island property more than twenty years and most of these persons own a residence.

Years Owned Island Property

Number of Years	N	%
0-5	18	10.7
6-10	31	18.3
11-20	26	15.4
21-30	20	11.8
31-40	27	16.0
41-plus	43	15.4
Total	165	97.6

1

Type of Island Ownership

Own Residence?	N	%
Property Only	6	3.6
Residence	155	91.7
Total	161	95.3

Only a quarter of the respondents live on the island year around. However, forty four percent report that they would prefer to increase the amount of time they live on the island. Predictably, the highest percentages of respondents are in the island during the warm months. Significant, however, are the high percentages of respondents who are on the island during spring and fall.

Residence Status

Month in Residence	N	%
Full time now	41	24.2
Planned increase:5 yrs	75	44.4
January	68	40.2
February	68	40.2
March	76	45.0
April	104	61.5
May	133	78.7
June	154	91.1
July	161	95.3
August	159	94.1
September	149	88.2
October	126	74.6
November	87	51.4
December	74	43.7

About an equal number of respondents were male or female. Over fifty percent graduated from college. About a third of the respondents are retired.

Gender of Respondents

Gender	N	%
Female	86	50.9
Male	82	48.5
Total	168	99.4

Education

Highest Level of Education	N	%
Some high school)	2	1.1
High school graduate (4 years)	31	18.3
Some college (1-3 years) or business, technical or trade degree	37	21.9
Bachelor degree (4 years)	51	30.2
Graduate school	45	26.6
Total	166	98.2

2

Employment Status

Categories	N	%
Not Retired	105	62.1
Retired	61	36.1
Total	166	98.2

Current Water Use

The majority of respondents receive their water from the Prudence Island Utility Corporation. Only a quarter use filters, but two fifths do limit overall water use. Less than fifty percent drink the water. Over a third have a cesspool.

Source of Water

Source	N	%
Prudence Utility Corporation	109	64.5
Prudence Park Water Association	17	10.1
Private well	29	17.2
Total	155	91.7

Response to Water Quality

Responses	N	%
Use filter	43	25.4
Overall limit use	72	42.6
Limit use for laundry	25	14.8

Uses of Water

Uses	N	%
Drinking	73	43.2
Laundry	109	64.5
Lawn or garden	64	37.9
Wash car	30	17.8

Waste Disposal

System Type	N	%
Septic system	95	56.2
Cesspool	62	36.7
Total	157	92.7

Plans for Development

The majority of these islanders have not made major changes in their residence, and do not intend to in the next five years. A third have increased the space in their residence or are planning to do so. Two fifths have winterized or are planning to do so.

Building and Remodeling

Actual and Planned	Last 5 Years		Planned next 5 years	
Development Type	**N**	**%**	**N**	**%**
Increase the amount of space	32	18.9	26	15.4
Winterize	47	27.8	22	13.0
New well	15	8.9	4	2.4
Upgrade septic system	29	17.2	28	16.6

Sale and Transfer to Family Members

Actual and Planned	Last 5 Years		Planned next 5 years	
Sale/Transfer	**N**	**%**	**N**	**%**
Attempt sale	2	1.2	7	4.1
Transfer to family member	26	15.4	19	11.2

Fifty four persons reported that they owned vacant lots. Of these 54, 68% have no plans to build and only 9% plan on selling or subdividing.

Use of Vacant Parcels

Actual and Planned	Last 5 Years		Planned next 5 years	
Vacant Lot Uses	**N**	**%**	**N**	**%**
Lot is buildable	27	50.0		
Leave all vacant	40	74.0	37	68.5
Sell one or more	1	1.9	3	5.6
Subdivide	1	1.9	2	3.7
Build cottage and sell	0	0	2	3.7

Island Life

Not surprisingly, walking and water activities are the most common activities.

Outdoor Activities on the Island, Respondent and Guests

	Number of times in the last 5 years				
Activities	**1 -2**	**3-10**	**10 plus**	**Total N**	**Total %**
Going for walks	2	18	138	158	93.5
Quohogging/fishing	3	27	125	155	91.7
Swimming	1	25	125	151	88.8
Boating	8	36	93	137	81.2
Bird watching	16	36	71	123	72.8
Biking	11	41	60	112	66.2
Jogging	14	19	35	68	40.2
Hunting	1	14	25	40	23.7
Water Skiing	9	14	9	32	18.9

Appendix 5: Monitoring Protocol

Groundwater Level

For each well, the groundwater level is determined using a Heron Instruments Water Level Indicator (model: Little Dipper). The instrument is dropped vertically into the well housing and will audibly 'beep' when the sensor comes in contact with water. Depth to water is read from the polyethelene tape (from which the sensor is suspended) to the nearest 1/100th of a foot where it intersects with the top of the well housing. Time and depth to water are recorded on the monitoring data sheet.

Note: In the event that the water level sensor is not functioning, a fiberglass tape with attached padlock can be used in most instances (the exception being the Tiger Beetle site where a standard tape measure must be used to accommodate the narrow well housing). It is necessary to listen for an audible splash and attempt to adjust the measurement to the water surface as accurately as possible.

Stream flow

Stream velocity is recorded in feet per second (ft/sec) for each 6 inch vertical component of monitored streams using a Global Water Flow Probe (model: FP101).

Steps:

1. A fiberglass tape measure is secured tautly to two points on either side of the stream (most often to permanently installed spikes) to serve as a guide and a static reference point for the measurement of stream stage.

2. Position the flow probe so that the arrow in the prop housing faces downstream. Use the bottom button to scroll through functions until "AVGSPEED" is displayed.

3. Press the top button for three full seconds to clear previous measurements (i.e. reset to zero).

4. Beginning at the appropriate water edge (REW or LEW – see data sheet) insert flow probe at the first 6 inch interval (indicated at the one and half foot mark on the suspended tape) in which water is flowing and of sufficient depth to rotate the sensor. Probe should be placed at 6/10th of depth and held in that position for a minimum of 40 seconds. Record average speed measurement on data sheet in appropriate interval position from origin.

5. Repeat steps 3 and 4 for each successive interval in which water is flowing and of sufficient depth to spin probe propeller.

6. At specified distance from origin (indicated on data sheet for individual monitoring sites) measure and record stage. This is the distance between the tape measure reference line and the water surface.

Notes: (1) Stream flow is the sum of the products of stream velocity times cross-sectional area for all individual stream segments and is computed after raw velocity data has been added to the dataset. (2) Measurements of stream velocity and computations of stream flow (or discharge) are in accordance with USGS standards for stream flow measurements.

Appendix 6: Monitoring Data Sheet

STREAM FLOW & GROUNDWATER LEVEL MONITORING

Data Sheet

Date: ____________

Site: ___________________________
Stage (at _________ **) =** ___________
Start Time: _________

Tape Reading	Distance from Origin	Velocity (ft/sec)
6	**6**	
2f	**12**	
6	**18**	
3f	**24**	
6	**30**	
4f	**36**	
6	**42**	
5f	**48**	
6	**54**	
6f	**60**	
6	**66**	
7f	**72**	
6	**78**	
8f	**84**	
6	**90**	
9f	**96**	

Site: ___________________________
Stage (at _________ **) =** ___________
Start Time: _________

Tape Reading	Distance from Origin	Velocity (ft/sec)
6	**6**	
2f	**12**	
6	**18**	
3f	**24**	
6	**30**	
4f	**36**	
6	**42**	
5f	**48**	
6	**54**	
6f	**60**	
6	**66**	
7f	**72**	
6	**78**	
8f	**84**	
6	**90**	
9f	**96**	

Site: ___________________________
Stage (at _________ **) =** ___________
Start Time: _________

Tape Reading	Distance from Origin	Velocity (ft/sec)
6	**6**	
2f	**12**	
6	**18**	
3f	**24**	
6	**30**	
4f	**36**	
6	**42**	
5f	**48**	
6	**54**	
6f	**60**	
6	**66**	
7f	**72**	
6	**78**	
8f	**84**	
6	**90**	
9f	**96**	

Groundwater Levels

Well	Time	Depth
Farnham Farm		
Rossi		
Silvia		
Prudence Park I		
Prudence Park II		
Barn Swallow		
Tiger Beetle		
Broadway		
Pier Rd.		
Fire Station		
Collamati		
Collamati 2		

Stage Measurements: Indian Springs at REW 27", T-Wharf at LEW 33", Mill Creek at LEW 54", West Side at LEW 18", Bay Avenue at REW 42", Conservancy 1 at LEW 12", Conservancy 2 at LEW 46"
*LEW/REW refers to left/right edge of water when facing downstream

Pier Road Well

Monitoring Dates	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006									17-Sep	14-Oct	26-Nov	10-Dec
2007	20-Jan	18-Feb	25-Mar	22-Apr	28-May	10-Jun	8-Jul	24-Aug	16-Sep	7-Oct	28-Oct	22-Dec
2008	13-Jan	9-Feb	9-Mar	19-Apr	10-May	1-Jun	29-Jun	24-Aug	21-Sep	19-Oct	23-Nov	4-Jan
2009	1-Feb	8-Mar	5-Apr	26-Apr	16-May	7-Jun	12-Jul	12-Aug	20-Sep	1-Nov	29-Nov	31-Dec
2010	10-Jan	31-Jan	21-Mar	11-Apr	23-May	20-Jun	27-Jul	16-Aug	19-Sep	11-Oct	23-Nov	17-Dec
2011	16-Jan	19-Feb	13-Mar	29-Apr	15-May	5-Jun	17-Jul					

Monthly Record	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006								27.563	27.208	29.333	20.750	22.667
2007	22.375	22.792	20.167	20.667	23.458	21.708	27.021	29.083	35.042	37.083	38.917	37.250
2008	26.375	22.583	19.792	22.333	22.250	24.438	26.875	31.583	31.333	25.750	25.708	22.917
2009	22.375	22.083	21.500	21.833	22.500	25.792	22.542	24.417	27.125	22.642	22.292	21.150
2010	22.640	21.150	20.650	21.100	25.300	24.600	30.510	33.780	35.800	37.050	31.100	29.010
2011	25.820	22.150	21.560	21.630	23.000	23.300	25.250					

1-mo. ave.	23.917	22.152	20.734	21.513	23.302	23.968	26.440	29.285	31.302	30.372	27.753	26.599
2-mo. ave.		23.034		21.123		23.635		27.896		30.837		27.176
3-mo. ave.		22.267			22.927			29.009			28.241	

Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006									1	1	1	1
2007	1	1	1	1	1	1	1	1	2	4	4	4
2008	2	1	1	1	1	1	1	2	1	1	1	1
2009	1	1	1	1	1	1	1	1	1	1	1	1
2010	1	1	1	1	1	1	1	3	3	4	2	1
2011	2	1	1	1	1	1	1					

Summary Statistics - All Dates

Min	Max	Mean	Median	60th Percentile	75th Percentile	90th Percentile	95th Percentile
19.792	38.917	25.611	23.379	25.463	27.297	33.906	37.052

Broadway Well

Monitoring Dates	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006									17-Sep	14-Oct	26-Nov	10-Dec
2007	20-Jan	18-Feb	25-Mar	22-Apr	28-May	10-Jun	8-Jul	24-Aug	16-Sep	7-Oct	28-Oct	22-Dec
2008	13-Jan	9-Feb	9-Mar	19-Apr	10-May	1-Jun	29-Jun	24-Aug	21-Sep	19-Oct	23-Nov	4-Jan
2009	1-Feb	8-Mar	5-Apr	26-Apr	16-May	7-Jun	12-Jul	12-Aug	20-Sep	1-Nov	29-Nov	31-Dec
2010	10-Jan	31-Jan	21-Mar	11-Apr	23-May	20-Jun	27-Jul	16-Aug	19-Sep	11-Oct	23-Nov	17-Dec
2011	16-Jan	19-Feb	13-Mar	29-Apr	15-May	5-Jun	17-Jul					

Monthly Record	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006									8.583	6.500	4.333	6.000
2007	5.458	6.167	4.333	5.417	6.833	6.583	9.417	12.042	14.292	14.958	16.500	14.000
2008	6.250	5.083	2.375	6.021	5.688	7.167	7.625	8.775	8.000	7.063	6.167	5.708
2009	5.625	5.542	5.250	5.167	6.208	7.250	5.833	7.000	7.208	5.625	5.604	5.250
2010	6.320	5.667	5.292	5.563	7.333	6.625	9.500	10.600	13.200	12.810	7.790	6.420
2011	6.340	4.950	5.260	5.350	6.350	6.780	6.990					
1-mo. ave.	5.999	5.482	4.502	5.504	6.482	6.881	7.873	9.604	10.257	9.391	8.079	7.476
2-mo. ave.		5.740		5.003		6.682		8.642		9.824		7.777
3-mo. ave.		5.327			6.289			9.219			8.315	

Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2006									1	1	1	1
2007	1	1	1	1	1	1	1	4	4	4	4	4
2008	1	1	1	2	1	1	1	1	1	1	1	1
2009	1	1	1	1	1	1	1	1	1	1	1	1
2010	2	1	1	2	1	1	1	3	4	4	1	1
2011	2	1	1	1	1	1	1					

Summary Statistics - All Dates

Min	Max	Mean	Median	60th Percentile	75th Percentile	90th Percentile	95th Percentile
2.375	16.500	7.255	6.340	6.749	7.479	12.196	14.029

Appendix 8: PIWD request

PRUDENCE ISLAND WATER DISTRICT
P.O. BOX 93
PRUDENCE ISLAND, RI 02872

July 26, 2011

Robert Stankelis
Reserve Manager
NBNERR
55 S. Reserve Drive
Prudence Island, RI 02872

Dear Mr. Stankelis,

At its meeting of July 16, 2011, the Board of Directors discussed the possibility of assuming responsibility for the fresh water well and stream monitoring currently being carried out by the district in collaboration with NBNERR. At this meeting, the board agreed that it should be the district's responsibility to carry out the field work associated with this monitoring project.

The PIWD board requests that NBNERR allow district employees to borrow the reserve's equipment to carry out this work. The board agrees that it will be responsible for maintenance and repair of this equipment while it is in the possession of the district. This equipment includes:

Global Water Flow Probe Model FP101 – replacement value $700
Heron Instruments "Little Dipper" Water Level Indicator – replacement value $400
Keson Open Reel Fiberglass Tape (model OTR1050) replacement value $25

The PIWD will provide NBNERR with the data gathered during these monitoring activities, and requests that NBNERR maintain the database and keep the PIWD updated on the status of the Broadway and Pier Rd wells.

Best regards,

Patricia Richard, Treasurer
Prudence Island Water District