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Fall 2013 | Water Resources + Climate | Portfolio of Academic Paper Critiques

ITEM 1: *Global Hydrological Cylcles and World Water Resources*

Oki, T., & Kanae, S. (2006). Global Hydrological Cycles and World Water Resources. *Science*, *313*(5790), 1068–1072. doi:10.1126/science.1128845

Summary:

Water scarcity has the potential to become a serious threat in the near future. Freshwater accounts for 2.5% of all the water on Earth, and much of that is not readily accessible. Aquifers located relatively close to the surface of the earth, in comparison to deep groundwater aquifers, are easily accessible. Yet, average recharge rates of such reserves are on a time scale magnitudes greater than the human timescale. “Global Hydrological Cycles and World Water Resources” beautifully emphasizes that only with proper renewable freshwater resource (RFWR) management can we avoid regionally experiencing periods of extreme water-stress.

Freshwater availability is fickle. Current usage rates for both blue water (conventionally drawn waters from rivers and groundwater) and green water (evapotranspired water to non-irrigate croplands) are well below even half of the availability, yet these average rates are deceiving when practically evaluating how much water is available at a given time and place. Seasonal variability alone limits the availability of freshwater; additionally, regional availability greatly varies depending on the water source. Further, the freshwater usage rates of 10% and 30% for blue and green water, respectively, only accounts for human consumption. As we know, there are demands outside of human usage for RFWR, which the Oki & Kanae article fails to address.

Looking spatially at water withdrawals and quantitatively using the water scarcity index, assessment of RFWRs can be conducted. Due to major human impact on the hydrological cycle, human interventions are also incorporated into water resource models; these considerations amount to a approximately 2.4 billion of Earth’s population living in “highly water-stressed areas.” The “Virtual Water Trade,” as described in the paper, essentially proposes importing the goods that require unavailable water to produce instead of using large amounts of energy to transport the water to the water scarce area. Oki & Kanae fail to address the potential unintended consequence of creating unbalanced local economies dependent on imports. Particularly developing nations would be susceptible to this, as they are less like able to finance water transports and would succumb to this “Virtual Water Trade.” It is possible that the intention was for this to be presented as a temporary solution for water stressed areas, but it is not clear from the publication.

Interestingly the paper ends with on the prediction Climate Change will likely accelerate the water cycle. I found the authors point poignant that, although we currently withdraw only about one tenth of RFWR (blue water), extreme events due to climate change may increase vulnerability in highly-water stressed areas. A very convincing case for utilizing the well-developed hydrological sciences to implement preemptive water management policy has been presented.

Strengths:
1. Clearly demonstrates the need for carefully considered water management strategies
2. Water Cycle Acceleration prediction was well developed
3. Anticipated Increased water stress due to Climate Change extreme weather argument

Weaknesses:
1. Non-human consumption of RFWRs is not addressed
2. Virtual Water Trade (VTW) proposal is unclear
3. Impacts directly related to were not considered/expressed with regard to VWT

Potential Further Discussion:
1. Are there other and/or more efficient ways to evaluate water stress? The article discusses evaluating temporal variability, are there other factors tat may be used to evaluate RFWR issues?
2. What types of specific RFWR management techniques/programs/policy can be implemented to reduce water-stressed areas?

ITEM 2: *Potential Impacts of a warming climate on Water Availability in Snow-Dominated Regions*

Barnett, T. P., Adam, J. C., & Lettenmaier, D. P. (2005). Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature*, *438*(7066), 303–9.

Summary:

Observed and predicted surface warming trends globally are expected to have significant impacts on the hydrological cycle; particularly in regions where the water supply is driven by melting snow and/or ice. The primary change would be a shift in seasonality of melt; peak melt would move from summer and autumn (a time of peak need) to winter and early spring. The authors support their hypothesis with observed changes in water supplies driven by land ice/snow regionally around the globe, and climate models. Additionally, they evaluate the limitations of current climate models, highlighting uncertainty that forcing of the hydrological system due to increased aerosols and clouds in the environment. Surface temperatures could serve to increase forcing melt in a positive direction, but also increased cloud albedo can serve to cool by limiting incoming solar radiation. Even observational data has demonstrated regional cooling, but aerosols also serve to warm areas of the atmosphere where glaciers exist. They conclude that without the without the foresight to implement appropriate water storage systems, water shortages will certainly occur. Furthermore, these actions may not be adequate, and significant changes to lifestyle, industry and agriculture are necessary.

Strengths:
1. Both observational and prediction data are used in predicting the seasonality of snowmelt-dominated regions.
2. Quantifying economically (with GDP) the percentage of the world at risk with the shift in seasonality of these water resources.
3. Thorough discussion of 2 major modeling challenges and therefor limitations in our predictions: aerosols/clouds and glaciers/ice sheets.

Weaknesses:
1. A brief explanation of why Greenland and Antarctica, the largest ice sheets are excluded in this study and models used for this study should have been included.
2. Data evaluation of snowmelt-dominated regions appears broad and very inclusive.
3. Very limited discussion of the type of "strategic planning" areas threatened by future water availability in snow/ice supplied water resources should be considering.

Potential Further Discussion:
1. What economic ramifications can be predicted with the shift in seasonality of snowmelt driven water resources?
2. What are some ways we can reform industrial, agricultural and day-to-day use that will not considerably affect lifestyle and development and is cost effective?

ITEM 3: *Drought-Induced Shift of a Forest-Woodland Ecotone*

Allen, C. D., & Breshears, D. D. (1998). Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. *Proceedings of the National Academy of Sciences of the United States of America*, *95*(25), 14839–14842.

Summary:

The authors hypothesize that climate-shift sensitive ecotones (the boundaries between ecosystems) can be used as a barometer to qualitatively evaluate the rate of climate change and predict future climate effects in wooded ecotones in the future. They looked at woody vegetation, which has a longer life-span and therefore can be used to look at persistent changes in the ecosystem using remote sensing data and observational insitu data. Additionally, many data sets were utilized to understand the dynamics of the ecosystem, such as: modern drought records, insect populations, geographic locations of vegetation, human-induced fire suppression, and soil erosion. The authors were able to identify the specific physical areas of the ecotone when there has been a rapid shift related to drought in their opinion. This data is used to conclude that other semiarid ecotones across the globe, which are expected to experience drought due to climate change are also at risk for such rapid change. The authors did not extrapolate as to what such rapid changes in these areas would mean to the ecosystems in which they outlie.

Strengths:
1. Very thorough explanation of methodology and subject area selection.
2. The evaluation of many parameters (fires, soil erosion, insects, forest fragmentation, etc) that express the dynamics of vegetation mortality due to climate change strengthened the authors argument and provides credibility to their method.
3. Their use of models and projections into the future based on observations in modern history gives relevence to the research and leaves room for further inquiry.

Weaknesses:
1. Data constraints wrt the available photographs (limited time series) and amount of coverage (full and partial mixed).
2. It is suggested that rapid mortality-induced shifts have occurred in the past, but no paleo or remote sensing data is available to supports the suggestion. It should be explained why the authors believe this.
3. Only a single species was considered; the argument would be stronger if these trends were identified in more than one species within varying wooded ecotones.

Potential for Further Discussion:
1. What are other parameters within ecotones that can be analyzed to evaluate the effects of climate change? And could any of the already analyzed parameters and/or effects be justified within a static ecosystem?
2. Can we uses this data to extrapolate the effect of drought on non-ecotone wooded ecosystems? Why or Why not?

ITEM 4: *Changes in Precipitation with Climate Change*

Trenberth KE. (2011). Changes in precipitation with climate change. *Climate Research*, *47*(1-2), 123–138.

Summary:

The author presents evidence for several already observed and projected changes in global precipitation in this paper. Key changes that have been identified include: the Clausius-Clapeyron (C-C) Effect, "it never rains it pours," "rich get richer, poor get poorer," increase in moist instability and subsequent stronger storms, rain suppression in areas due to "upped ante," widening of the tropics, wind current changes due to SST changes, weakening winds due to addition of energy to the atmosphere via latent heating ("more bang for the buck"), reduced snowpack resulting in less soil moisture. I was most interested in 4 of these concepts. The C-C Effect explains that with increased temperatures the atmosphere's water vapor holding capacity is greater; this along with other mechanisms reduces the frequency of rain events, but increases the amount of water or intensity ("it never rains but it pours.") Also, increased evaporation within our current circulation system means amplification of current precipitation patterns. "Rich get richer" are those who already receive rain will receive more creating more flood events, and those who already receive minimal rain ("poor") will receive less and experience more drought ("poorer.") And finally warmer temperatures will increase rain precipitation over snow precipitation, which will reduce snow packs, also higher temperatures will melt snow packs sooner (spring). This causes water shortages in the summer when temperatures peak and low soils moisture which leads to more drought, wildfires, and heat waves.

Strengths:
1. Very thorough review of scientific work related to changes in precipitation due to natural variability and Climate Change. Also, concise explanation of the science and pertinent processes gave breadth to the paper.
2. Well-organized addressing different types of data considered, changes in patterns over time, impacts, how this corresponds to what is being modeled, and what this implies for the future. All information builds on each other to provide the reader with a clear picture.
3. Limitations in the models, data, and understanding of physical processes were clearly stated.

Weaknesses:
1. Very thorough review of scientific work related to changes in precipitation due to natural variability and Climate Change. This is also a weakness because every argument made an opposing one was presented, at times diluting the overreaching points. And social impacts to the physical impacts were not once mentioned.
2. The length. Although all of the material serves to create a full view of all interacting processes and physical impacts, the amount of information and redundancy in some sections forces the reader to work very hard to extract all of it.
3. Nearly 30% of the cited material for reference, the author is first author on. This is no a huge issue, but seeing that the author is the only author on this paper there could inherently be biases in data interpretation presented.

Potential for Further Discussion:
1. What implications does the concept of "the rich get richer, the poor get poorer" have for social planners, water managers, etc, with reared to adaption in the future. What areas have already begun to experience these phenomena?
2. How does ENSO generally affect the general trend of increased hydrological cycle activity? What could be its impact in the future when the hydrological cycle has changed significantly?

ITEM 5: *Long-Term Aridity Changes in the Western United States*

Cook, E. R., Woodhouse, C. A., Eakin, C. M., Meko, D. M., & Stahle, D. W. (2004). Long-Term Aridity Changes in the Western United States. *Science*, *306*(5698), 1015–1018. doi:10.2307/3839431

Summary:

The Western United States is currently in the midst of a 15-year drought; at the time of the Cook paper (published in 2004, written circa 2002-2003) the drought had been persisting for about 3 years. The investigators primarily utilized paleo-climate tree ring proxy data to evaluate long-term drought anomalies in the region. Using tree rings and spatially gridding data allowed for reconstructions spanning 1200 years and over more than half of the continental United States. The 1200-year period included the Medieval Warming Period (MWP), a time known for increased warmth and hydroclimate variability. The Drought Area Index (DAI) was applied to each of the grid points in order to "rank" them, opposed to using actual "drought values." The DAI values were compared to 9 independent indicators including tree stumps in lakebeds and river channels, anomalous fire scars, elevated charcoal in lake sediments, high levels of lake salinity, sand dunes, and other records.

Cook and others found that when examining the data, the current drought area affected is comparable and not unlike the modern droughts of the 1930s and 1950s. But, temporally the length of the current drought (~4 years at the time) is unusual for modern history (the past 104 years at the time of the paper). When compared to the droughts of the MWP, the current drought is not as significant. It was concluded that the Western US could and has experienced more severe droughts than any observed in the 20th century. It is hypothesized in the paper that warmer climate conditions may have forced the MWP mega droughts. Climate model data suggests anthropogenic warming of current climate conditions due to increased GHGs in the atmosphere. This could mimic the suspected warmer temperatures during the MWP. Finally, natural oscillations are presented as potential forcing mechanism for further drought in the region. Ocean-Atmosphere climate models are used to support the hypothesis that further warming conditions can induce more La Nina-like conditions, which are already known to promote drought conditions in the Western US. If this is to happen, the potential for unprecedented megadroughts in the area exists.

Strengths:
1. Using proxy data and independent indicators allow us to see a fuller picture regarding climate variability and the megadrought potential of the region from a historical POV, while still considering modern observational data. Modern climate conditions are within a pluvial period, but he paleoclimate perspective can see multi-decadal variability outside of this.
2. Corroboration of statistical data with physics-based dynamical models to support prosed future forcings strengthens over all forecasts, as there are some weaknesses with purely statistical data as mentioned below.
3. Consideration of natural climate variability's effect on drought conditions is strength because it considers external influencing factors on drought persistence.

Weaknesses:
1. No alternative arguments for the development of more frequent and persistent droughts was presented other than anomalously warm climate conditions were presented.
2. Statistical analysis is very useful and highly reliable, but at times excludes dynamical relationships/interactions, which can lead to a less complete view of the environment and feedbacks.
3. Consideration of natural climate variabilities effect on drought conditions is a weakness because the effect of climate change could change some natural oscillations, thereby affecting this hypothesized effect on drought.

Questions for Further Discussion:
1. What greater impacts does this research have on water resource projection and management? If there is a potential for warming to induce period of megadrought, what steps could be taken to begin adaption in the Western US?
2. What independent indicators of severe drought are we currently witnessing with relation to the 15-year drought in the West that can be related to this study?

ITEM 6: *Peak Water Limits to Freshwater Withdrawal and Use*

Gleick, P. H., & Palaniappan, M. (2010). Peak water limits to freshwater withdrawal and use. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(25), 11155–11162. doi:10.2307/20724038

Summary:

In this paper the authors compare water resource capacity to that of oil, using Marion King Hubbert's peak oil production theory (Hubbert peak theory). The theory claims that for a non-renewable resource (oil), production in a specific region follows a bell-shaped curve. Pre-peak of the curve, production increases due to technology and infrastructure improvements until peak is reached. The post-peak declines because the resource is finite and is being depleted. Although freshwater is generally considered a renewable resource globally, regionally this is not always the case. Waters can be constrained by location, recharge rate, and other factors. Some uses degrade water resources thereby limiting the potential uses. Renewable freshwater is compared to oil with respect to three factors: consumptiveness, substitutability, and transportability. Where oil is always consumed, not all uses of water are consumptive (water is not always lost to the hydrologic cycle or for future use). Where oil can be substituted for other forms of energy, water is not replaceable in processes in which it is used. Oil's high market makes the high cost of transport to areas lacking this resource look comparatively small. On the other hand, water does not carry a significant value and thus it's cost of transport is very high. This means that instead of transporting renewable waters to regions lacking them, those areas would prefer to tap non-renewable resources. The authors also propose the three following "peak water concepts":

1. *Peak Renewable Water* – when waters from groundwater basins with fast recharge rates, rivers/streams, rainfall capture reach their limit. The limits on these renewable flows of water are determined by the maximum amount of withdrawal allowed from the system.
2. *Peak Nonrenewable Water* – when waters that are effectively not renewable, one example are groundwater aquifers with slow recharge rates ("fossil aquifers"), use exceed recharge or are polluted/contaminated. Another example of nonrenewable waters includes glaciers experiencing greater mass loss than accumulation (due to climate change) that supply freshwater to rivers, reservoirs, etc.
3. *Peak Ecological Water* – when the value of waters that are captured exclusively for human consumption (and do not support the ecosystem) is less than the amount of ecological harm being inflicted.

The authors indicate that the United States has already passed peak water, which does not mean the US will run out of water, but that we have passed most efficient water usage. Also, the idea of peak ecological water and conclusion that globally many regions have already passed it is the most compelling point in the paper. Considering these peak constraints in relation to the type of water resource available is important for water managers.

Strengths:
1. Figures, particularly graphs demonstrating peak relationships, are clear and demonstrate theory well. 2. Comparative analysis of oil and water was well articulated.
3. The idea of peak ecological waters is a novel concept, and I feel very important. Often the externalities of human consumption on the environment are ignored or discounted, so development of its own metric is valuable.

Weaknesses:
1. I believe a fundamental weakness is incorporating peak renewable water in this theory. The fact there is a finite amount of water available annually does not fit well with peak theory, which suggests a rise and then decline in the resource.
2. Given that renewable waters are the vast majority used globally (as reported by the authors), and depletion of these are not a danger, the authors would have done better to explain why these peak theories with respect to nonrenewable and ecological waters are important in the future. I would have liked more discussion on peak ecological waters in general.

3. I interpret Figure 9 showing US water withdrawals flat lining while GDP to continue to grow an indication of more water use efficiency. I think a more effective figure would have included ecological degradation and aquifer depletion of some measure.

Potential for Further Discussion:
1. How will peak rates be affected considering regional climate change predictions in the future? Could predicted changes in the hydrologic cycle be used by water managers to adapt to water issues we are facing now?
2. How could we begin to quantify peak ecological water and ecological degradation versus economic benefit? What indicators can be used?
3. What would happen if we economically valued water resources to the same degree as energy? What unintended social consequences could result from increase the monetary value of water in attempts to make transport and/or desalination more economically viable?

ITEM 7: *Stationarity Is Dead: Whither Water Management?*

Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. (2008). Stationarity Is Dead: Whither Water Management? *Science*, *319*(5863), 573–574. doi:10.1126/science.1151915

Summary:

The Milly paper asserts that stationarity, the assumption that water resources fluctuate but the measures of distribution (e.g. mean and variance) minimally do, is not longer valid when managing water. Due to climate change, the hydrologic cycle has and continues to change. Alterations in precipitation, evapotranspiration, water vapor capacity and concentration, river discharge rates, and surface run-off are all cited as indicators of a changing hydrologic cycle. Until recently, pleas for a move away form stationarity were ignored due to uncertainties in climate change projections. But as models have been validated against past observational data, becoming more robust, it has become apparent that the anthropogenic forcing of the climate and persisting CO2 in the atmosphere will prevent a regression to stationarity.

An appropriate conceptual framework of the hydrologic cycle is necessary to confidently manage water resources and the associated impending hydroclimate risks (e.g. invest in useful infrastructure). The authors suggest non-stationarity variables should be based on historical samples/data using random probability distributions (stochastic simulations) to model the hydroclimate. This approach is expected to allow for adaption as the climate changes. Additionally, the authors address other issues that may want to be addresses with current models as we are already considering revisions that will be more useful to water planners. A stable platform to enable consistent access to the data and forecasts was suggested. Also, the issue of spatial and temporal resolution was mentioned. Water managers operate on a regional scale, and would find regional climate models farm more useful than models with hundreds of kilometer grids. And managers would find useful small scale, surface-to-ground processes as well as other representations (e.g. land use change, water use, etc.) in implementing new infrastructure. Over all a call is being made to comprehensively revise the tools we use to manage our water resource in order to properly plan for the future.

Strengths:
1. Well articulated problem and theory as to why it is a problem (good correlation to climate change with scientific support from other papers).
2. An alternative simulation methodology was presented (stochastic).
3. Issues water managers might face with models, outside of the physical changes Earth is undergoing were presented (e.g. too coarse spatial resolution, poor information delivery, etc.).

Weaknesses:
1. An actual model simulation with output results using a stochastic method versus stationarity would have demonstrated if this approach is valid.
2. A specific case study of where stationarity predictions are failing water managers would have supported the claim of the paper.
3. More detail between the specific difference of stochastic simulations from stationarity, plus examples of which variables could be stochastically classified would have been helpful.

Potential for Further Discussion:
1. What types of hydrologic variables, given the changes in the hydrologic cycle due to anthropogenic climate change, can we expect?
2. What limitations due to data may we find when attempting to build higher-resolution simulations?

ITEM 8: *Transitions Towards Adaptive Management of Water Facing Climate and Global Change*

Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. *Water Resources Management*, *21*(1), 49–62. doi:10.1007/s11269-006-9040-4

Summary:

Global climate change is increasing the uncertainty for water managers, primarily due to the increases in probabilities of (what we currently consider) extreme events (e.g. drought and flooding). Claudia Pahl-Wostl asserts that in order to sustainably manage water resources, adaptive management systems must be implemented. Firstly, the "water system" includes the environmental aspect, the technical infrastructure and policy, and the social component of water as a resource. Adaptive management is increasing the adaptive capacity of a system, which includes the ability for the system to change based on new observations and continually seeking to improve on policies and practices. This can only be done by constant evaluation of the state of nature and the effectiveness of the current system components (policies and practices). The primary goal would be to continually increase the amount of climate (environmental) variation the system could withstand.

The primary requirements for an adaptive water system are: the acquisition of new data to input into the system, and the system's ability to process new information and change according to it. Essentially, the system must be able to learn from observations in the natural system and learn from actions that have occurred within its own integrated system. Also, Pahl-Wostl emphasizes the importance of "social learning." Social learning is considered the collective action amongst a number of various stakeholders in the water system to resolve conflicts since all parties are interdependent on one another due to the shared water resource. Multi-actor collaborations are necessary to improve technical, political and social quality (the speed and effectiveness of) the water system. Despite the difficulties to adjust to and adaptive system, projects such as the NeWater project have demonstrated success through integrating the hard and soft sciences required to make changes. Lastly, Pahl-Wostl states that both regional and global considerations must be made to made to fully understand water resource problems and find solutions.

Strengths:
1. Thorough overview of what adaptive water management is, the history of it, the requirements needed and its outlook.
2. HarmoniCOP example of social learning and collective action demonstrated the concept well.
3. NeWater Project exemplifies he argument of difficulties in transitions to an adaptive water system, but a solution to increasing success.

Weaknesses:
1. A description of current (non-adaptive) water systems was not included to allow for comprehensive comparison of the two strategies.
2. Case studies of adaptive and non-adaptive water systems and their corresponding social and policy structures were missing.
3. An example of how a non-adaptive water system has failed due to the increase in extreme events would have given the authors purpose and hypothesis more legitimacy and salience.

Questions for Further Discussion:
1. What obstacles can you foresee with the social learning aspect of Pahl-Worstl's suggestion? Could there be resistance to collective action between the difference stakeholders (e.g. authorities, experts, interest groups, and the public)?
2. Most people looking at the water management issues in light of climate change emphasize the need to manage on a local level, how do you think Pahl-Wostl intends for this paper to be used on a global scale?

ITEM 9: *Singapore Water: Yesterday, Today and Tomorrow*

Authored by Teng Chye Khoo

Summary:

This report, produced by the Public Utilities Board of Singapore (PUB) reviewing past and present water management of the city-state, and projecting future water resources begins by outlining the issue of water in this region. Singapore is a small island with a population of over 4.5 million people with a UN ranking of 170/190 for freshwater availability. Despite the wealth of rainfall each year, Singapore's small size limits rainwater catchment. In the 1960s Singapore was already feeling the stress on freshwater resources and experienced times of water rationing and foreign import of water from Malaysia. Over a ten-year period beginning in the late 1970s, Singapore launched an interdepartmental effort to clean the polluted waterways of the city, which was successfully completed in 1987. The cleanup allowed for improvements on water resource infrastructure such as separating out supply water, waste water and stormwater. The big push in the twenty-first century by PUB to sustainably manage water resources included developing many local catchments within the city, becoming water independent, and developing technology to purify and reuse wastewater. As the country has limited land, catchments of rainwater were a huge endeavor, but proved to be highly worth the investment and some reservoirs serve dual infrastructure purposes to act as flood barriers. The NEWater technological development and implementation involved financial investment for both research and development. Additionally, PUB invested a lot of effort to gain public acceptance prior to revealing the policy of reusing wastewater; this appears to have been highly successful. Using waster water (or "used water") has, in a sense closed the water cycle: rain catchment, use, treatment, and reuse. Singapore has also developed the largest desalination plant in the world. PUB is now focusing on the future of water in the country with three challenges: increasing long-term supply, optimization, and sustainability. Due to increasing demand as a function of increasing population and GDP, Singapore is focusing on forecasting that demand and planning for it. To satiate the demand, Singapore is investing in technology R&D as the resources simply do not exist. Optimization includes spatially optimizing the land by moving infrastructure, or technologically optimizing by upgrading older technologies. And environmental sustainability is taking into account the system as a whole ("holistic approach"). PUB is considering climate change in their future plans. PUB also emphasizes the need for openness in the managing dialogue and cooperation among different groups.

Strengths:

1. Description of the public education and communication programs to build approval of NEWater.
2. Comprehensive review of issues of past present and future, and some implied background on the cultural and social state of Singapore that influences management strategies.
3. The entire report highlights the proactive and innovative hard and soft actions the nation of Singapore took to address it's water resource issues, and prepare itself for future growth.

Weaknesses:

1. The report was produced by PUB of Singapore, reporting on their efforts in water management. Inherently there will be bias to emphasize the positive improvements.
2. There was no mention of the potential backlash from the public when initiating NEWater or the validity of their concerns (e.g. risks).
3. Very few references, which makes this report less credible and appear more as a personal account.

Potential for Further Discussion:

1. What timescales can we expect for the hard infrastructure improvements versus soft policy efforts?
2. What unstated resources/advantages could have been available to Singapore PUB to make their water management strategies successful (e.g. politically, financially, socially, etc.)?