

# Groundwater flow systems in eastern half of Fukushima prefecture and its surrounding

## ~calculation of mean residence time based on CFCs and SF<sub>6</sub>~

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### Introduction

The tsunami occurring at the time of Tohoku Pacific Ocean earthquake on March 11, 2011, caused Fukushima Nuclear Power Plant accident happen to emit radioactive nuclei in the atmosphere. In Fukushima, groundwater has been used as not only agriculture but daily purposes. Since the radioactive nuclei move slowly in the groundwater system, it is necessary to continue observing groundwater for a long term to understand movement process and residence time. For that reason, it is important to understand groundwater flow system. The purpose of this study is to document the groundwater flow systems of the eastern half of Fukushima prefecture and its surrounding i.e. south of Miyagi and north of Tochigi prefectures. Here, the residence time of groundwaters collected in November, 2016 in July and October, 2015 and discussed based on the result of CFCs and SF<sub>6</sub> analyses.

### Results

The study area was divided into three areas; area A (Hamadori and eastern slope of Abukuma mountains), area B (between the ridges of Abukuma and Echigo mountains included Nakadori), and area C (the southernmost part of Sendai plain).

The groundwaters from area A contained CFC-12 60-5000ppt, CFC-11 10-8000ppt and CFC-113 5-300ppt. The concentrations were lower in the groundwaters from the plains along the seashore than those from mountain area Those from area B contained CFC-12 100-10000ppt, CFC-11 10-10000ppt and CFC-113 8-500ppt. The concentrations were lower in those from the northern plain than the others. Although the concentrations of SF<sub>6</sub> were obtained only for the samples collected only from the central to southern part of the plain of this area, most of these waters contained excess SF<sub>6</sub> over the atmospheric one. The groundwaters from area C contained CFC-12 190-1000ppt, CFC-11 50-2000ppt and CFC-113 10-60ppt. Although the ranges of those value were overlapped with those of area A, only a few samples had the high concentrations.

Combination of the obtained concentrations suggest the four different models of groundwater flow i.e. Piston flow(PFM), Exponential mixing(EMM), the intermediate of PFM and EMM(PFM/EMM), Binary mixing(BMM). Some data could not be explained by these models. Most groundwaters can be explained EMM, BMM or PFM/EMM. Therefore, most of the studied groundwaters, especially from the plains, have more than two origins. However, the groundwaters from the mountain area had a single origin. Calculated mean residence times were 6-82 years and about 70% these were 15-40 years old. Groundwaters having short residence time within 15 years were concentrated from the slope to the foot of mountains over areas A and C. Many groundwater were 15-30 years old in the area B, while those older than 31 years were concentrated on foot of the mountains and in the plains. The residence time of areas A and C was generally longer than area B.

### Discussion

Samples dissolving excess  $\text{SF}_6$  were concentrated on the plain of area B probably because factories near the sampling sites discharged it in the 1990s, which was calculated recharge ages. According to Fukushima prefecture prevention of global warming promotion center, the amount of  $\text{SF}_6$  discharge in Fukushima would reach the peak to cause the dissolution of the excess  $\text{SF}_6$ .

In the plains between Abukuma Mountains and Echigo Mountains (Nakadori), precipitations recharged on these mountains and the plain part were mixed in the aquifer. It must be the reason why many groundwaters can be applied to mixing model. The mixing model can explain the groundwater flows especially at the foot of mountains because there is meeting of groundwaters originated from the different recharge areas.

The shorter residence time of groundwater from the areas A and C than those from B would be due to the elevations of recharge areas. Groundwaters in areas A and C were mainly recharged on the lower Abukuma mountains and those in area B did mainly on the higher Echigo mountains; i.e., paths to the sampling sites at the lower altitudes are comparatively short from the Abukuma mountains than Echigo mountains.

## Groundwater flow transition in the southwestern Tokyo Metropolitan Area after restriction of groundwater abstraction

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Regional groundwater flow located in the southwestern Tokyo Metropolitan Area (southwest region of Kanto plain) is previously called “Urawa groundwater flow (e.g., Kino, 1970)”. Groundwater in this region has been developed largely since 1950s, and huge amount of groundwater abstraction has induced land subsidence not only in upland area but lowland area in this region. Thus, the national government and local governments have restricted groundwater abstraction in stages. That is, history of groundwater development and restriction largely differ between the areas in this region.

Although the groundwater development has affected the regional groundwater flow, transition of the regional groundwater flow is not clarified. This study aims to clarify transition and present situation of the regional groundwater flow in this region based on the dataset of groundwater levels that has been monitored by Tokyo metropolitan government and Saitama prefectural government to contribute to sustainable groundwater management.

We present the characteristics of transition and present situation of the regional groundwater flow.

Keywords: groundwater level fluctuation, groundwater development, municipalities, restriction of groundwater abstraction, groundwater basin management, Tokyo Metropolitan Area

## Evaluation of subsurface warming in the Tokyo metropolitan area, Japan

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Three-dimensional subsurface temperature distribution and its long-term change were examined by repeated observations of temperature-depth profiles at monitoring wells from 2000 to 2016 and groundwater temperature monitoring from 2007 or 2012, to evaluate effects of regional groundwater flow and environmental changes due to urbanization on subsurface thermal environment in the Tokyo metropolitan area, Japan.

Subsurface warming has been found at shallow depths in the whole study area by our previous study (Miyakoshi et al., 2010). Especially, subsurface temperature beneath the city center was particularly high not only at shallow part but also deep part. In contrast, relatively low temperatures were found beneath the suburban area. Comparison result between past subsurface temperature data (2003 to 2005) and present subsurface temperature data (2013 to 2016) shows that subsurface warming is found at the shallow part in the last 9 to 10 years. Subsurface temperature increase in the city center is larger than the suburban area, and the temperature difference between both areas shows an increasing tendency. Additionally, subsurface warming in the present data was recognized deeper than the past data. This result suggests that distribution of subsurface warming is expanding toward the deeper part.

Subsurface monitoring data showed constant warming rates at observatories in the southeastern area of Saitama Prefecture and the eastern area of Tokyo Metropolis. These observatories are located in the alluvial lowland, and the warming tendency was formed by effects of surface warming due to urbanization. On the other hands, subsurface warming was not a constant rate at observatories in the southwestern area of Saitama Prefecture and the western area of Tokyo Metropolises. These observatories are located in the Musashino Uplands, and the warming rate show a time and a depth variation. Additionally, subsurface temperature changes were found at not only the shallow part but also deeper part than 100m in this area. These complex subsurface temperature changes are recognized around areas where significant changes of hydraulic heads were observed, and it was considered that subsurface thermal environment was affected by artificially-induced groundwater flow changes. Results of this study suggest that mechanism of subsurface warming is able to be evaluated by combined analysis of geological condition, groundwater flow and subsurface temperature changes.

This study was conducted as a part of Civil Engineering Support & Training Center, T.M.G.- Akita Univ. - AIST Joint Research and Saitama Pref. -Akita Univ.- AIST Joint Research.

Keywords: subsurface temperature, groundwater flow, subsurface warming, groundwater development, urbanization, Tokyo metropolitan area

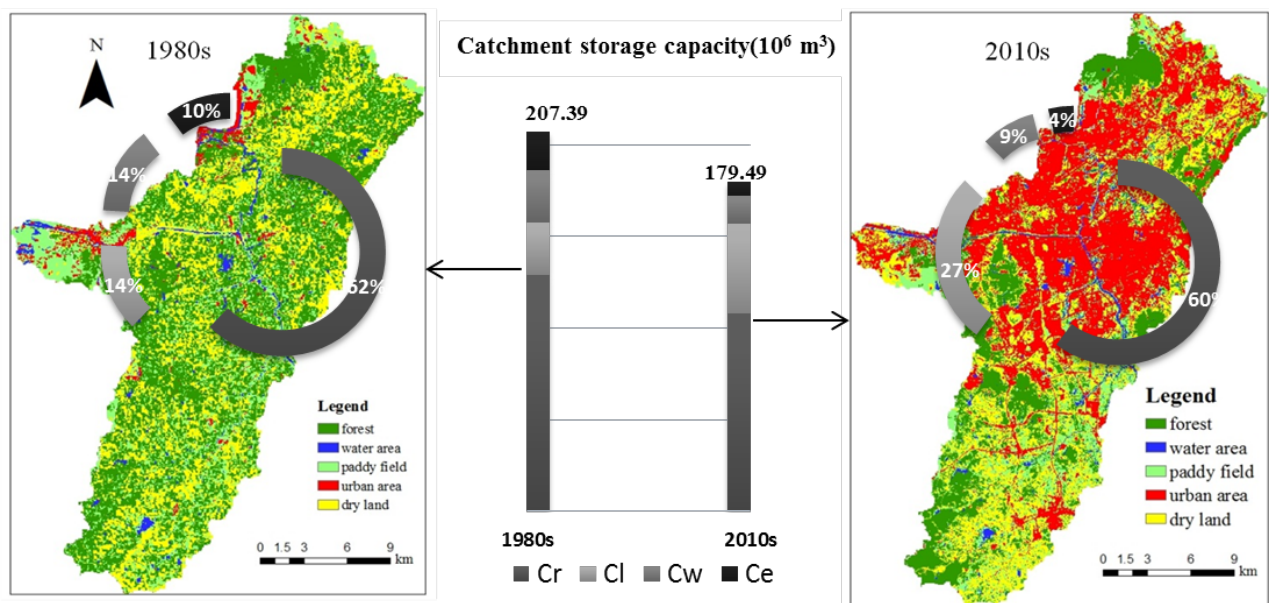
# The effects of urbanization on catchment storage capacity of surface water –a conceptual model in plain catchment in Yangtz river delta

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Hydrological processes in Yangtze river delta area have been significantly changed due to rapid urbanization in the last 30 years. A conceptual model involving four modules - river network, lakes/reservoir, wetland/floodplain, and ecological land use –was proposed to evaluate the surface water storage capacity, as well as its temporal variation and its structural sensitivity from 1980s to 2010s in Qinhuai River Basin, Yangtz River Delta. The data sources include MSS/TM images, thematic maps, Digital Elevation Model, and gauged hydrological data from 1980s and 2010s. The main findings indicated that, 1) the main driver of the storage variation is the construction land expanded and forest decrease; 2) although the total water area increased, the complexity and stability of river network declined; 3) the surface water storage capacity of Qinhuai river catchment decreased by 13.45%, from  $207 \times 10^6 \text{ m}^3$  to  $179 \times 10^6 \text{ m}^3$  during the study period; 4) the lake/reservoir storage is the most sensitive module to the urbanization, while the river network module serves as main contributor to the total storage. More effects should be made in the protection and restoration of the low-level rivers, forest and wetlands to protect and restore the catchment storage capacity. The results of the study would provide support in policy formulation and intervention strategies.

Keywords: Storage capacity, urbanization, conceptual model, effect analysis, Yangtze River Delta



## Urban flooding risk mapping using hydrodynamic and GIS models

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Rapid urbanization and unpreventable climate change have resulted in severe urban flooding events that hit worldwide cities more frequently and heavily. An instructive and up-to-date monitoring and evaluation on the distribution of flooding risks in cities is necessary and valuable for urban planning. This research applied two major approaches in current urban flooding studies: hydrodynamic and GIS models in a case study in London, ON, Canada. From the hydrological view, hydrodynamic models employ a series of hydraulic equations to calculate the motion of water from fluvial/pluvial-based sources. The inputs of such hydrodynamic models are often composed of detailed hydrological parameters (e.g. river crossing section), which need to be inputted by experienced hydrodynamic experts. Besides the high standard of hydrological expertise, hydrodynamic models involve heavy calculation and are often difficult to run with high spatial resolution data. For end-users who do not have hydrological background, the two features impede the easy access to hydrodynamic models. On the other hand, GIS models can be easily equipped with multiple high spatial resolution GIS layers. But in GIS models, hydrodynamic physics does not apply and the key parameters are often generated from historical flooding events or empirical models. Therefore, a bond between hydrodynamic and GIS models needs to be made in urban flooding studies, in order to take advantage of both models strength. This study used the water level result derived from one open-source hydrodynamic model (PCSWMM) as a known flooding event. According to the hydrodynamic model result, the parameters that the GIS model requires were decided. In this way, the GIS model can be considered as a simplification of the used hydrodynamic model. The used GIS layers in this study include DEM (digital elevation model), slope, curvature, landuse/landcover, and road system density. As a result, an urban flooding risk map is generated using the hydrodynamic-model-trained GIS model.

Keywords: Urban flooding, GIS model

## Characteristics of ground water under the central Osaka

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On the west side of Osaka plain, several clay layers accompanying repeated sea level change accumulate in layers, and the gravel layer between the clay layers forms a submerged aquifer where abundant underground water resides. On the other hand, due to the severe ground subsidence caused by the massive pumping up of factory water in the 1960s, pumping is currently strictly regulated. However, in recent years, especially in Osaka city, consideration is being made on effective utilization of groundwater, such as the promotion of underground water use project as regenerative thermal energy. Therefore, we conducted survey of water level, water temperature, and water quality using existing observation holes near Nakanoshima from around Osaka Station for the purpose of acquiring background data on the properties of groundwater at the present time. The aquifer covered in this study is a sand gravel layer (1st aqueduct layer: Dg1) distributed beneath the clay layer (Ma13) of the Holocene, and the gravel layer (the second caught aquifer: Dg 2) distributed under the clay layer (Ma12). Regarding the water quality, we analyzed the composition of the principal components etc. for groundwater sampled 4 times in total in June, September, November 2016 and January 2017. As a result, it was revealed that both Dg 1 and Dg 2 were reductive and showed a Na - Cl type water quality composition, especially Dg 1 had a higher salt concentration. In addition, mineral composition analysis (XRD) of the fine grains obtained when filtering with a membrane filter of 0.45  $\mu\text{m}$  was carried out, and it was found that amorphous iron oxide was included together with detrital grains. The abundance and the mineral composition of such fine particles present in the groundwater are important information in searching for effective use of groundwater in the future.

Keywords: ground water, borehole, database, water quality

# A study on the water environment in Shingashi river basin

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## 1.First

Some rivers flowing through urban areas in Japan still have problems with water quality, and it is important to grasp the water environment of the river in the current urban area in order to promote the conservation of the water environment. Hosei University has continued to conduct research on the Shingashi river basin that flows through suburbs of Tokyo since the 1930s, and in recent years it has been conducting water quality surveys in cooperation with civil society groups. Here we will clarify the water environment of the current Shingashi river basin, based on the results of the water quality survey conducted four times from 2013 to 2016.

## 2.Region overview

The Shingashi river basin is located in 10 cities and 1 town in Saitama Prefecture, 6 cities and 1 town in 3 wards in Tokyo. The Shingashi river of mainstream is a first class river belonging to the Arakawa water system. The flow path extension is 34.6km, and the tide zone is about 16km from the confluence point with the Sumida river. In addition, the catchment area is 411km<sup>2</sup>.

## 3.Survey method

In the Survey on familiar water environments conducted in June every year, citizen groups provided water collected, and in the laboratory we measured pH, RpH, EC and analyzed TOC, Analysis of major dissolved components is carried out.

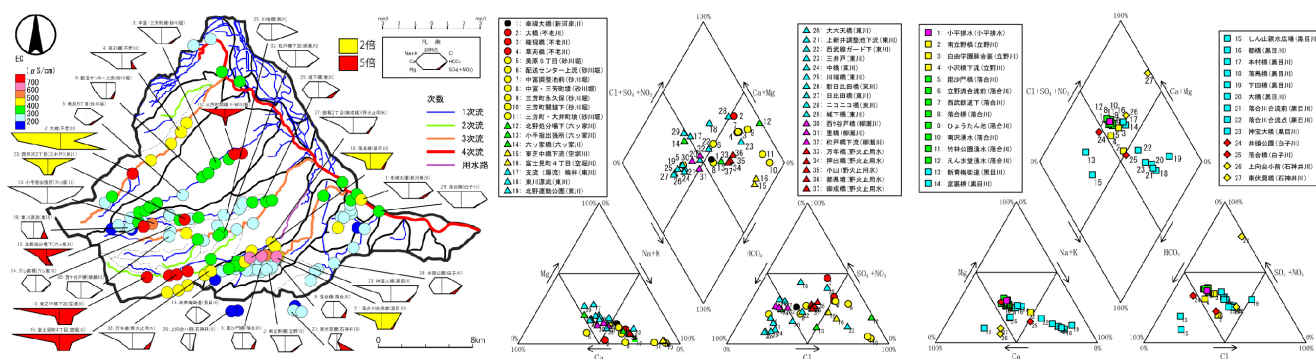
## 4.Results

As a result of the survey, various water quality is distributed in the Shingashi river basin, but in the upstream area of each river, the Calcium bicarbonate type water quality composition is shown, the downstream side tends to show the composition of sodium chloride type at the downstream side, this suggested the effect of domestic wastewater. It also detects nitrate ions, it is also anticipated that agricultural fertilization will affect rivers.

## 5.Conclusion

Because there was bias at the analyzed points, we could not grasp the water environment throughout the basin. In future, we aim to deepen collaboration with civil society groups and to grasp the water environment of the entire Shingashi river basin.

Keywords: Shingashi river basin, Water Quality, Urbanization





## Nitrate contamination in spring water and its relation to land use at upper and lower river terraces

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Groundwater contamination including nitrate has long been regarded as an important social problem. Numerous earlier studies have implicated land use at the ground surface as the cause of such contamination. To elucidate land use effects in this study, we investigated water quality composition including nitrate of spring waters in the northern part of Morioka city, Iwate Prefecture. Spring water A and B samples were taken on the terrace at a mountain side. Also, C was obtained from a paddy field site on the terrace. D and E were obtained under the terrace. Land uses on terraces included paddy fields, houses, ironworks, poultry farms, electrical parts factories, and cafeterias. Water quality compositions of A and B samples tended to be similar. Compared to B, spring water C showed higher  $\text{NO}_3^-$ . Whereas D had higher values of  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{K}^+$ , and  $\text{HCO}_3^-$  than B. In the E sample,  $\text{Na}^+$  and  $\text{K}^+$ ,  $\text{Cl}^-$  concentrations were lower than in D;  $\text{NO}_3^-$  was conspicuously present. Annual changes in water temperature were observed in C, D, and E, suggesting that water was flow in the surface layer. The change in water temperature was more pronounced in D than in E; their groundwater flows are expected to be different. The cause of increased  $\text{NO}_3^-$  and  $\text{SO}_4^-$  in C was inferred as paddy field fertilization. Regarding D, tendencies showed increased  $\text{K}^+$  and  $\text{Cl}^-$ , along with increased  $\text{Na}^+$  and  $\text{Ca}^{2+}$  differing from C. Influences other than paddy fields irrigation and fertilization, such as households or industrial wastewater, were inferred. Moreover, D and E exhibited different water quality compositions, suggesting that groundwater was affected by narrow range of land use.

Keywords: groundwater, contamination, land use

## Distribution and geochemistry of gas seepage on Boso peninsula, Chiba

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Within the area of Southern Kanto gas field in Chiba, with methane concentration of >99%, natural gas seepage is observed widely on land in the central part of Kujukuri plain to Otaki. Such gas has been used as a fuel by local residents, however, it may cause an accidental explosion and agricultural damage. In addition, if the gas is continuously released from the subsurface environment to atmosphere through the seepage, the impacts on the local carbon cycle should be taken into account. In this research, we aim to characterize the source, migration and seep processes of these gases by analyzing their chemical and isotopic compositions. Gas samples were collected from the boundaries between alluvial mudstone and sandstone or Kazusa Group, with a methane concentration generally of >75% and trace amounts of carbon dioxide and ethane with nitrogen from atmosphere. According to the methane/ethane ratio and stable carbon isotopic composition of methane, it is suggested that the majority of methane is of biogenic origin. Together with the stable carbon isotopic composition of carbon dioxide, it is considered that the methane is produced mainly by reduction of carbon dioxide and fermentation of acetate with some contribution of methane oxidation.

Keywords: gas seepage, methane, Boso peninsula

# **Hydromechanical Modeling of Urban Road Collapse and Land Subsidence Induced by Underground Facility Failure**

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As population of cities grow, the demands of underground developments increase accordingly. However, without careful consideration of urban hydrogeology and soil characteristics, those subsurface constructions could alter urban hydrogeology and consequently induce land deformation on the surface, which are potentially hazardous to local communities.

In particular, land subsidence and sudden road collapse phenomenon are one of major geohazard frequently occurring in many metropolitan cities of which underground facilities become gradually old. In most cases, these surficial collapses are known to be induced by the failure of near surface artificial underground structures and pipelines (e.g. water supply/ sewer lines, subway tunnels); however, exact hydromechanics process of collapsing which incorporated by groundwater and subsurface characteristics is not yet fully understood.

The purpose of this study is (1) to explore the feasible mechanism of land subsidence and road collapse in the urban areas, (2) to develop a hydromechanical model that simulates the moment of failure and quantify the interaction between pore pressure and associated effective stress field. The stability of collapsing area is also inferred using Columb Shear Failure (CSF) potential. Lastly, (3) using 2D and 3D models, a variety of possible scenario are tested to obtain quantitative relations between failure potential and hydrogeologic factors such as precipitation, aquifer heterogeneity and leakage events.

A fully coupled groundwater flow –deformation equation is used for solving an urban collapse problem corresponding to transient pore pressure changes by natural and anthropogenic factors. Preliminary numerical results show that the subsidence pattern and failure potential are closely related to the local fluid pressure change affected by groundwater leakage through cavities created by underground facility damage, and hydromechanical properties of the aquifer play important roles in either mitigating or exacerbating the collapse process.

Keywords: urban road collapse, fully coupled hydromechanical modelling, underground facility failure

## Case investigation of the efficiency degradation of open loop geothermal cooling and heating system(OLGCHS) in Korea

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This study was conducted to improve energy efficiency of open loop geothermal cooling and heating system (OLGCHS) showing low energy efficiency. When OLGCHS were installed, hydrogeological properties and groundwater yield were not considered. Therefore, various problems such as groundwater depletion, circulatory disturbance of groundwater, groundwater overflow, clogging by materials, and decrease of energy efficiency occur in many facilities which OLGCHS was installed and maintenance is very difficult. These circumstances have a negative influence on the spread of the OLGCHS in Korea. However, there is no proper investigation and cause analysis to solve the above problems. In this study, an advanced standing column well(SCW) was developed. In advanced SCW, wells used in OLGCHS are arranged in a row and these wells are connected using pipeline. Therefore, well depth was reduced and groundwater circulation was improved in the advanced SCW compared to a common SCW. In addition, installation cost can decrease and energy efficiency can increase. This research was supported by a grant(16CTAP-C116546-01) from Technology Advancement Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

Keywords: open loop geothermal cooling and heating system(OLGCHS), efficiency degradation, hydrogeological properties