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Spatiotemporal estimation of fresh submarine groundwater discharge across the coastal shorelines of Oahu Island, Hawaii

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ABSTRACT

The integrated hydrological model is a powerful tool that is used to assess the temporal distribution of fresh groundwater discharge especially in coastal areas. The coastal regions of Hawaii are examples of crucial natural resources for the Hawaiian economy and general ecological health. To fully comprehend the intricate interactions between coastal hydrology processes and ecosystems, it is necessary to evaluate the fresh submarine groundwater discharge (FSGD) at the Heeia shoreline using an integrated hydrological modeling technique. Under steady-state settings, the results showed that the present daily average of FSGD is around 0.43 m^3/days across 1 m of the shoreline. However, we showed that the FSGD values were considerably impacted by climate change, groundwater head of the coastal aquifer, recharge rate, and sea level rise, particularly by the end of the 21st century. The post-development FSGD fluxes were 1.5–3.5 times greater than the freshwater transported by the Heeia stream, demonstrating the considerable contribution of the FSGD to the coastal zones of Heeia. The results also showed an exponential association between the FSGD and the groundwater level for the coastal unconfined aquifer.

Key words: Fresh submarine groundwater discharge, Heeia watershed, integrated hydrological modeling, MODFLOW, SWAT

HIGHLIGHTS

- Fresh submarine groundwater discharge (FSGD) is one of the major hydrologic components.
- The integrated hydrological modeling technique is a powerful tool.
- FSGD has a robust role in biogeochemical and ecological health.
- FSGD is the main driver of freshwater and nutrient fluxes of Hawaii's coastal areas.
- FSGD is expected to significantly decrease due to climate change and sea level rise.

1. INTRODUCTION

Fresh submarine groundwater discharge (FSGD) is one of the major hydrologic components in the coastal areas of the Hawaiian Islands. FSGD discharges freshwater and nutrients into the Pacific Ocean across the ocean–land interface and plays a significant role in the biogeochemical and ecological health of near-shore and coastal areas (Moore 2010). A considerable amount of freshwater and dissolved nutrients are transferred from the coastal aquifer to the coastal marine environment through the energetic hydrological process, which is known as FSGD. For example, marine ecosystems are positively influenced by the FSGD through mitigation of the salinity concentration and modifying the pH predilection of the coastal waterways. After that, the marine life forms will be habilitated to sustain their permanence (Wang *et al.* 2022). The groundwater gradient between the coastal aquifer and the ocean is crucial to the process of FSGD, which is the primary driver of freshwater and nutrient fluxes for the coastal zones of the Hawaiian Islands (McGowan 2004). Thus, the amount of stored groundwater in aquifers and the hydraulic head that determines the flow gradient from land to ocean have a significant impact on the nutrients that are transported (Niencheski *et al.* 2007; Moore 2010; Ghazal *et al.* 2018b).

When compared to streamflows from watersheds, FSGD is the primary supply of freshwater for the maritime coast on the windward side of Hawaii's Oahu Island. (Dulaiova *et al.* 2015; Ghazal *et al.* 2018a). As a typical example, the Heeia watershed is one of them, which has a coastal zone of groundwater-dependent ecosystems.

The marine coastal ecology of the Heeia watershed is also regarded as providing major ecological services since it includes the largest protected coral reef system in Kaneohe Bay, which is one of the largest fishponds on the island of Oahu and the largest federally recognized wetland (Lowe *et al.* 2009). Understanding the spatial and temporal hydrological processes that take place at the boundary between the terrestrial and marine environments is crucial for protecting marine biodiversity and preserving native coastal ecosystems (Krause *et al.* 2017; Tsang *et al.* 2019). The natural nearby ecosystems are actively strengthened by freshwater flows. The availability of nutrients and light, for instance, has a significant impact on the growth of different kinds of plankton in water bodies including lakes, oceans, and wetlands. Plankton plays a significant role in decreasing greenhouse gas emissions in the coastal zone and serving as a vital source of food for large aquatic species (Palit *et al.* 2022). The health of marine coastal ecosystems depends critically on FSGD and freshwater flow from streams and rivers; thus, researchers, managers, and politicians worldwide have paid close attention to this interface (Discharge 2004). Consequently, a thorough understanding of the spatial and temporal FSGD is required to fully comprehend the linkages between ecosystems and coastal hydrological processes, including calculating the volume of freshwater discharged into coastal zones via surface runoff and FSGD.

As the flow magnitude of coastal waterways varies both spatially and temporally, estimating the FSGD is very challenging. The hydrogeological characteristics, climatic variability, and human activities of the region have an impact on FSGD. In general, direct field measurements, like those made using geochemical tracers, can be used to estimate the FSGD and the coastline's recirculated seawater (Peterson *et al.* 2009). This is considered the most adequate, but it is suitable only for a small-scale assessment. The coastal FSGD can also be estimated using a simplified water budget approach, for example, as it was used in previous studies (Oberdorfer 2003). However, the simplified water budget method lacks the inclusion of density-dependent groundwater flow and spatial heterogeneity, which could lead to unreliable results (Zhang *et al.* 2002) and thus FSGD estimation. Given the application of field measurement at a small scale and the limitation of a simplified water balance approach for estimating spatially and temporally varied FSGD, hydrological models like the Soil and Water Assessment Tool (SWAT) approach (Ghazal *et al.* 2020) and the MODFLOW approach for Oahu Island (Whittier *et al.* 2010) can be used. These models sufficiently consider a system's spatial heterogeneity and complexity and are thus expected to reasonably capture the spatiotemporal variation of FSGD. In addition, such hydrologic models can be used to assess the effects of climate, land use, and sea level rise (SLR) on watershed's water balance components such as evapotranspiration, recharge, streamflow, and freshwater quality, including FSGD along the coastline (McCoy & Corbett 2009).

To estimate the spatial and temporal FSGD throughout the shoreline of the Heeia watershed, this study used the fully distributed MODFLOW model (Whittier *et al.* 2010) with the watershed ecohydrological and semi-distributed SWAT model (Leta *et al.* 2016). The study examined how the Heeia watershed's coastline will be affected by the Heeia Coastal Wetland Restoration (HCWR) program, climate change (CC), and SLR. Finally, we compared the amount of fresh surface water flux and FSGD in the coastal zone of the watershed. Coupling the SWAT and MODFLOW models for estimating the spatiotemporal variation of FSGD along the coastal shorelines of Oahu Island has been done for the first time. The integrated (coupled) models have also been used to evaluate and compare the FSGD and streamflow contributions to the total freshwater discharges to the coastal zone of the Heeia watershed. The integrated models assessed the FSGD values for the pre-development and post-development periods, including under the proposed HCWR plan, CC, and SLR. Such studies are expected to serve as a tool to enhance our understanding of the importance of FSGD and streamflow values under different land use and climatic conditions for sustainable water resources management, coastal development, healthy coastal environments, and ecosystem functioning of the Heeia coastal areas.

2. MATERIALS AND METHODS

2.1. Study area

The coastline of the Heeia watershed is located on the windward side of Oahu Island, an interface between Oahu's largest fishpond and Kaneohe Bay (Figure 1). This coastline represents the estuary of freshwater in the coastal marine ecosystem through streams and FSGD (Dulai *et al.* 2016a; Ghazal *et al.* 2020). The coastal zone of the Heeia watershed is an alluvial plain to the fringing reefs. In addition, it is part of Heeia ahupua'a, which is typically a pie-shaped land division that extends from the uplands to the coastal plain and aquaculture in freshwater fishponds (Kakoo Oiwi 2010). On the other hand, this area is addressed in the Sea Grant program,

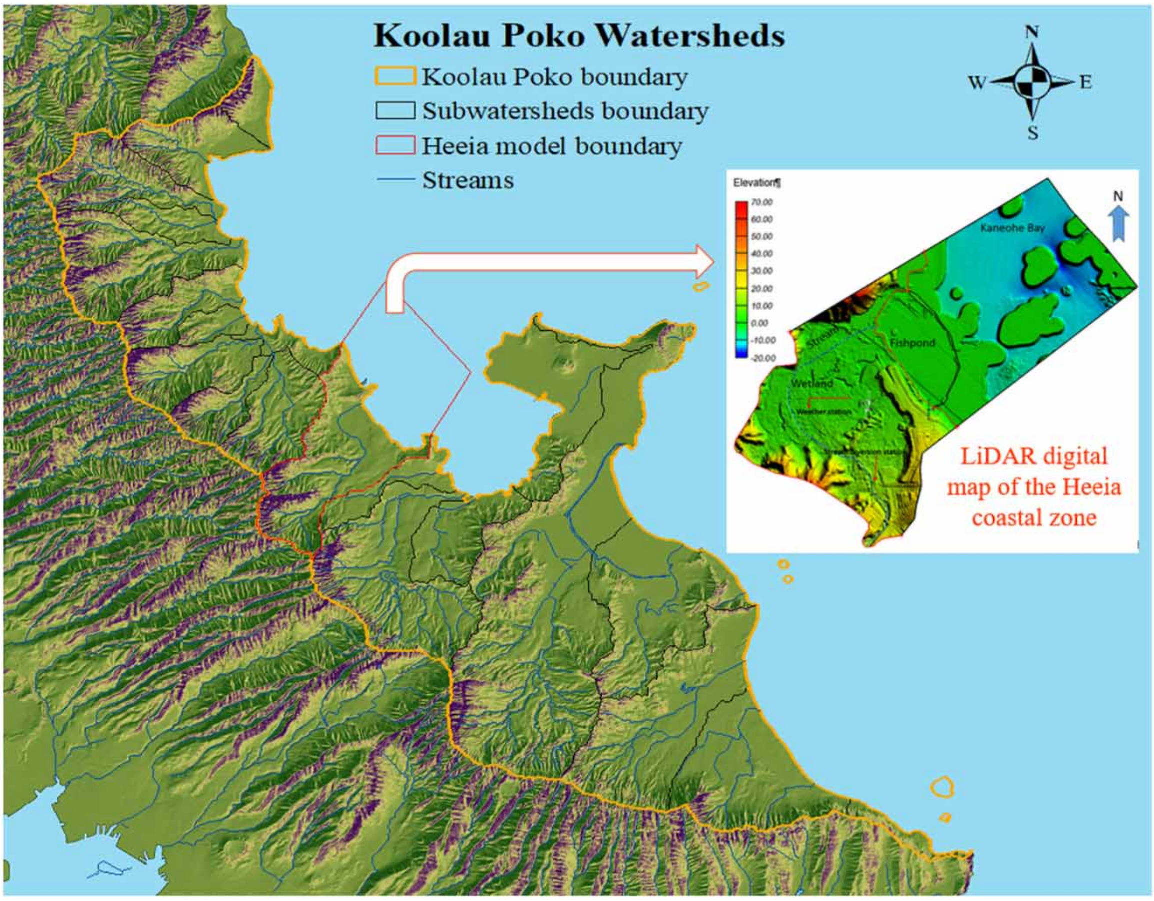

Figure 1 | A geographical map showing the Heeia coastal zone on Oahu Island, Hawaii.

which focuses on sustainable coastal development, hazard resilience in coastal communities, and healthy coastal ecosystems Sutton-Grier *et al.* (2015). Ghazal (2017) and Leta *et al.* (2016) provide a detailed description of the location, physical, climate, and hydrogeological features of the study area.

2.2. An approach using integrated hydrological modeling

We developed the USGS groundwater flow, the MODFLOW model for the Heeia watershed, and the SWAT model to meet the goals of this study. The predicted recharge coverage provided by the SWAT model as input data to the transient MODFLOW model serves as an illustration of the integrative interaction between these two models. Surface water flows into the ocean are also estimated by the SWAT. The SWAT model can continuously simulate watershed hydrological processes at different time steps and under different scenarios such as HCWR, CC, and SLR. The variation in recharge coverages of the coastal zones under these different scenarios is more accurately reflected in the spatiotemporal estimation of the FSGD (Leta *et al.* 2016; Ghazal *et al.* 2018a, 2020).

Details on SWAT model build-up, calibration, validation, and evaluation for the Heeia watershed can be found in our previous studies (Ghazal *et al.* 2020). The MODFLOW was used to estimate the groundwater flow along the coastline of the Heeia watershed. Specifically, the MODFLOW 2005 model for the Heeia watershed was conceptualized, developed, calibrated, validated, and assessed by our team for the Heeia watershed. By employing a cell finite-difference method, the MODFLOW model simulates three-dimensional groundwater flow in the ground-saturated layer of the Heeia watershed. While we considered SWAT application for the watershed part of the study area, the MODFLOW model area includes the aquifer of the Heeia watershed and extends into the ocean to cover the land–ocean interface and accurately simulate the flows along the coast (Figure 2). The MODFLOW modeling covers 21.7 km^2 that we discretized into 3,680 refined grid cells. As shown in Figure 3, the MODFLOW used three different boundary types: defined flux, head-dependent, and no flow boundary. The 7,136-m-long arc of the Heeia coastal littoral utilized the designated flux. Based

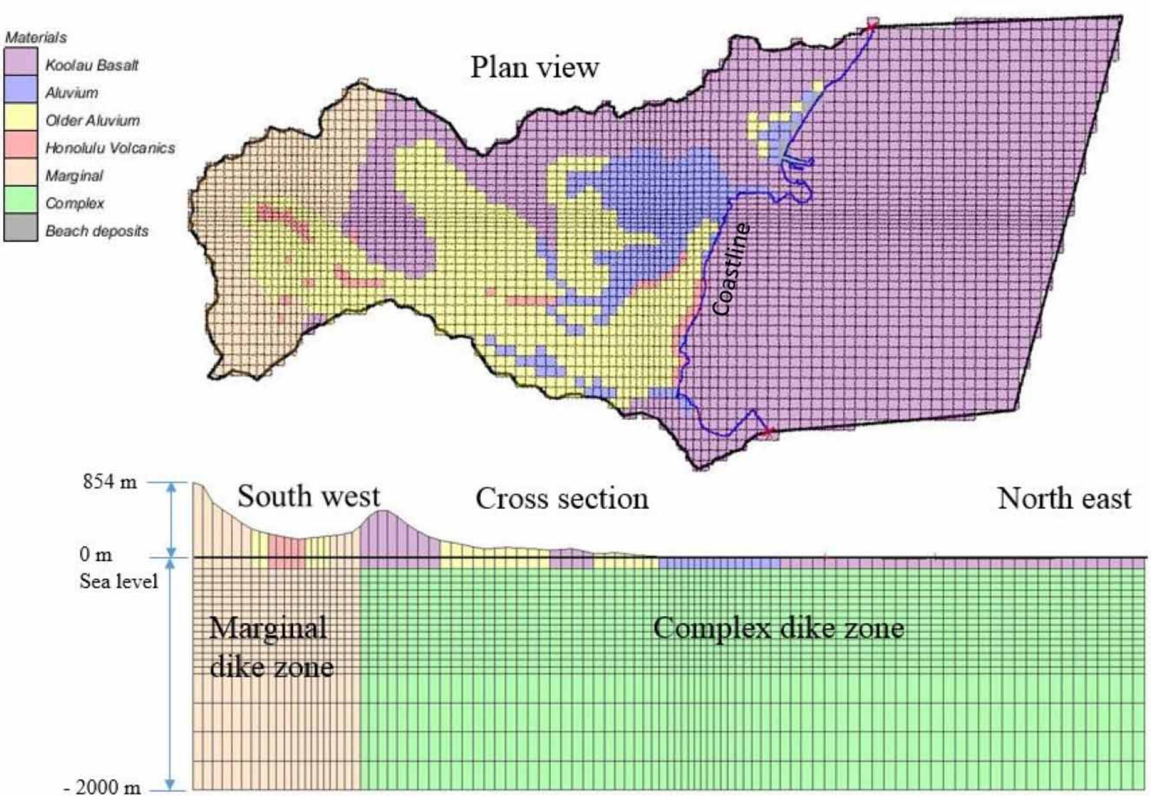

Figure 2 | The Heeia MODFLOW model's simulation region and the cross-sectional image of the hydrological components.

on the simplified assumption that the primary surface water divides and groundwater flow divides coincide and that the hydraulic gradient was equal to zero at the no-flow boundary, we assigned no-flow boundary conditions for the outer model boundary arcs (Huntington & Niswonger 2012). The observed water level piezometers inside the coastal zone and two flow stations are what determine the spatial and temporal FSGD assessment under various stress periods in daily timesteps (Ghazal 2017). We estimated FSGD under steady and transient conditions. We developed the MODFLOW models for the pre-development and post-development periods that cover the period from 1950 to 1959 and 2005 to 2014, respectively. At the Haiku Station, groundwater flow measurements were used to calibrate the MODFLOW model (Willems 2004). The initial stage of FSGD was represented by the pre-development phase. By using the previously published water balance approach for the pre-development period and assuming 46% of the rainfall values observed at the Mauka station, we were able to calculate the pre-development recharge (Ghazal *et al.* 2020). For the post-development period, which represents the anthropogenic effects, we used the SWAT model, which was calibrated and validated for the Heeia watershed in the previous studies (Ghazal *et al.* 2020), for estimating daily recharge.

2.3. Calibration, validation, and scenarios for the MODFLOW model

The inverse parameter estimate (PEST) method, which is already included in the GMS software packages, was used to automate parameter estimate for the MODFLOW model calibration parameters. The PEST technique was methodically modified using the input parameters until the discrepancy between the values of the computed and observed groundwater flows and heads was minimized (Doherty & Hunt 2009). In the unconfined aquifer system of the Heeia, the MODFLOW model was used to simulate both steady-state and transient conditions of groundwater flow. Groundwater storage does not alter in steady-state settings since constant inflows and outflows are equal at equilibrium. Furthermore, there is no time-dependent variation in the input data or the outputs. The dynamic system, in which variable inflows, outflows, and groundwater storage change over time, was represented by the calibration of the transient MODFLOW model of groundwater flow. As a result, it was regarded as the first step in analyzing the geographical and temporal distribution of

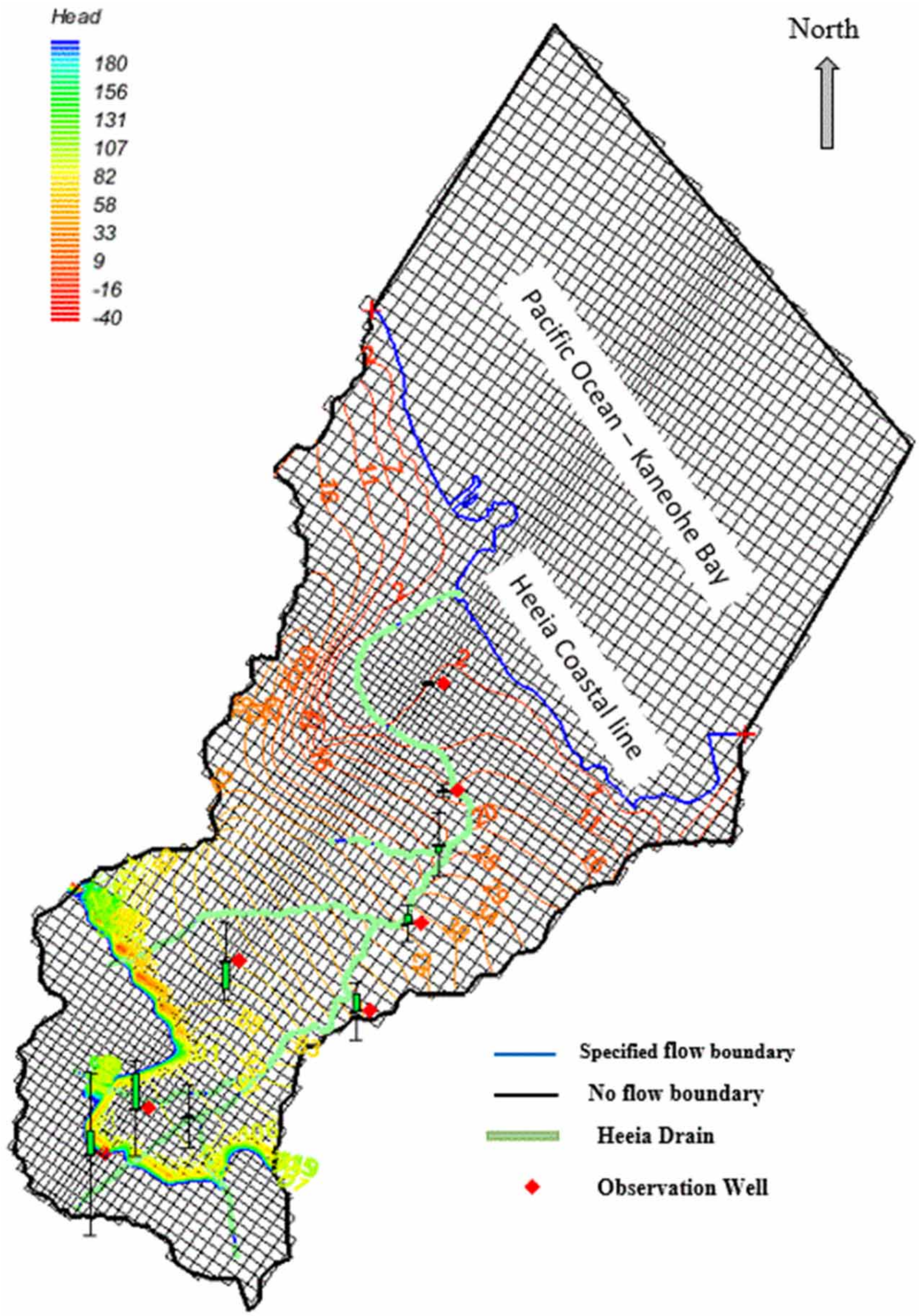

Figure 3 | Boundary conditions of the unconfined aquifer of the Heeia watershed.

FSGD during various stressors. Daily timesteps and stress periods were used to run the MODFLOW model throughout both the pre-development and post-development phases.

Two flow stations and two piezometers within coastal wetlands that measure actual water levels were used to calibrate the MODFLOW model. The Heeia watershed's seven average initial groundwater level wells and two stations that measure streamflow were used for the steady-state calibration's target approach. The transient model was calibrated using historical data on Haiku streamflow collected between 1950 and 1959 for pre-development. The model was then evaluated for the post-development period of 2005–2014. The calibrated steady-state model and the predicted hydraulic conductivities, storage coefficients, and drain conductance were used to begin the transient model calibration. Both the pre-developmental and post-developmental phases used daily timesteps and one stress period per day. The FSGD through the Heeia Coastal Shoreline was evaluated using the MODFLOW model under transient conditions and the SWAT model outputs. Additionally, various scenarios were employed to evaluate FSGD at daily stress intervals and timesteps. SLR, groundwater recharge, changes in land use and climate, and the hydraulic head gradient at the interface of the ocean and aquifer are the key forces and factors that propel and impact FSGD (Mulligan & Charette 2009). To represent the near, middle, and end of the 21st century, respectively, the sea level was raised by 0.12, 0.4, and 1.1 m based on the expected SLR of Hawaii (Rotzoll & Fletcher 2013). We used the Representative Concentration Pathway (RCP) 8.5 scenario to create these three SLR scenarios.

3. RESULTS AND DISCUSSION

3.1. MODFLOW model calibration

The anisotropic hydraulic conductivity of the aquifer as well as drain conductance are among the calibrated metrics. The results of the sensitivity analysis of the simulated model outputs show that changes in the horizontal anisotropic hydraulic conductivity of older alluvium material (HANI_60), recharge in the mountain zone (RCH_80), horizontal hydraulic conductivity of older alluvium (HK_30), horizontal hydraulic conductivity of Honolulu volcanic (HK_10), horizontal hydraulic conductivity of beach deposits (HK_20), recharge in the coastal land zone (RCH_100), recharge in the lowland zone (RCH_90), horizontal anisotropic hydraulic conductivity of Koolau basalt material (HANI_50), horizontal hydraulic conductivity of marginal material (HK_40), horizontal anisotropic hydraulic conductivity of complex material (HANI_70), and drain conductance had a significant impact on the simulated head and drain flow (Figure 4).

The steady-state calibrated MODFLOW results indicated that the computed head was highly correlated with the observed head (Figure 5). A strong model fit was also shown by the ratio of the standard error of the model residual (1.5) to the range of observations (7) (Table 1) (Puerto Rico Land Authority 2004).

3.2. FSGD assessment

According to the MODFLOW model's results under steady-state conditions, baseflow and FSGD values are responsible for 70 and 30%, respectively, of recharge during the pre-development phase. The recharge, baseflow, and FSGD values fell by 33, 37, and 53%, respectively, as compared to the pre-development (baseline) period. With less groundwater being recharged and more groundwater being withdrawn, FSGD showed a more dramatic decline (Figure 6). By the end of the 21st century, according to the SWAT model, the recharge values will decline

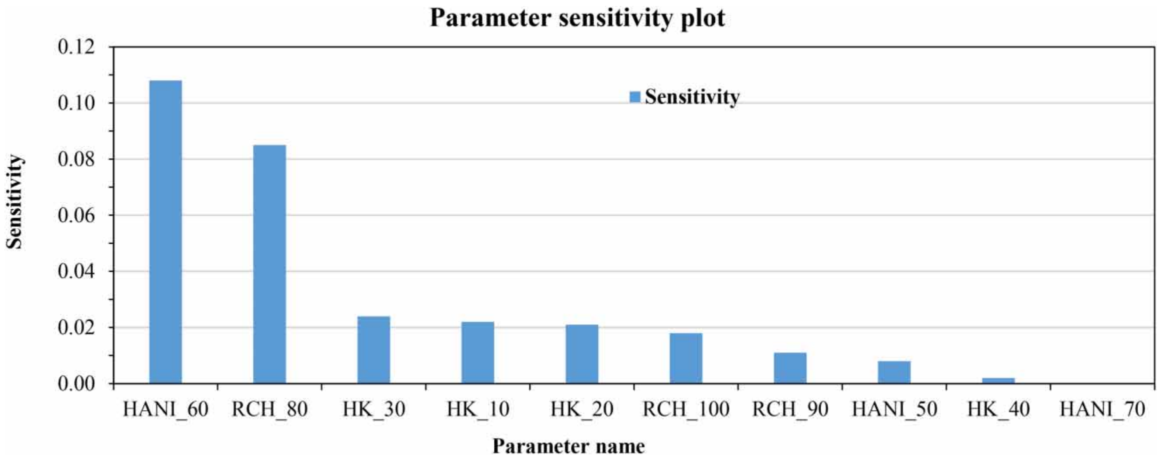

Figure 4 | Simulated groundwater head and baseflow and the MODFLOW model's parameter sensitivity.

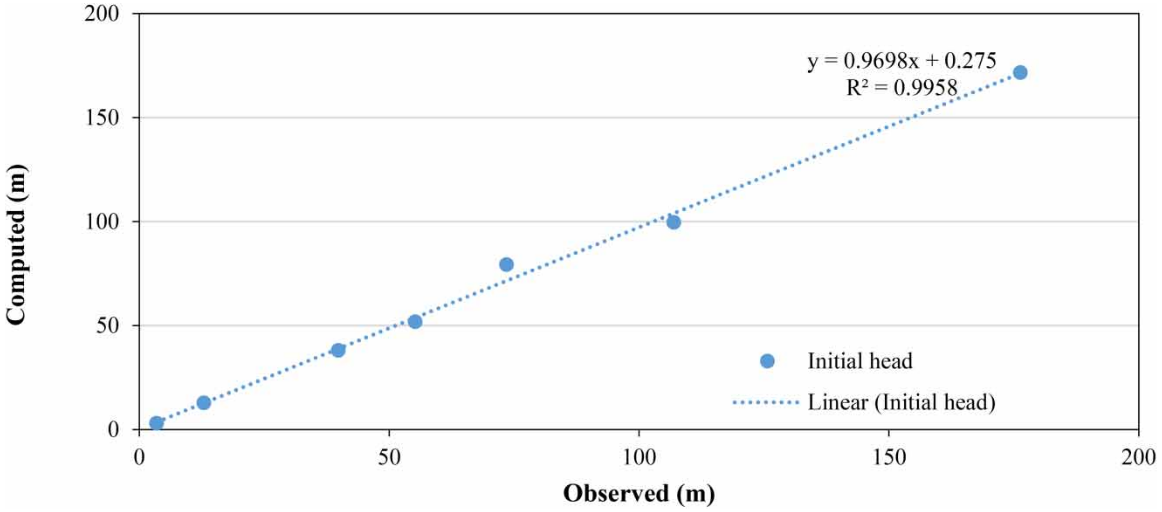

Figure 5 | Regression plot of estimated and observed groundwater heads in seven wells and two stream gauging locations in the Heeia watershed in steady-state simulation.

Table 1 | Statistical analysis of the groundwater head which was calculated and measured inside the MODFLOW model domain

Observed well name	Initial head (m)	Head interval	Standard deviation	Computed head	Residual head
Weather st.	2.98	0.3	0.15	3.46	−0.48
StreamDiversion_piezometer	12.79	1.4	0.71	12.95	−0.16
Kaneohe_well_lowland	38.01	3.8	1.94	39.82	−1.81
Kaneohe_well_upland	51.82	6	3.06	55.23	−3.41
Iolekaa_well	79.25	8	4.08	73.49	5.76
Haiku_well	99.58	10	5.10	106.97	−7.39
Haiku_DOT_well	171.6	17	8.67	176.32	−4.72

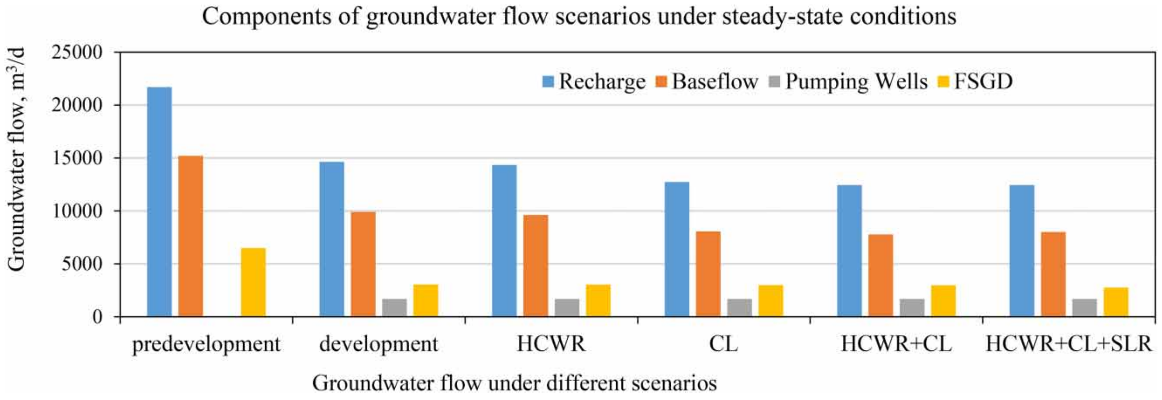

Figure 6 | Estimation of the groundwater flow under steady-state conditions with several scenarios, including the SLR, CC, and HCWR.

by 2% under HCWR, 13% under the RCP8.5 CC scenario, and 15% under the combined impact of HCWR and CC. The prior study contains further information (Ghazal *et al.* 2019, 2020). The HCWR, CC, combined HCWR and CC, and combined HCWR, CC, and SLR, respectively, would led to FSGD decline by 0.3, 1.9, 2.4, and 9.6% (Figure 6).

The effect on SLR by 1.1 m is consistent with the study conducted on Oahu Island (Rotzoll & Fletcher 2013). The results show that FSGD is very susceptible to groundwater withdrawals, SLR, and CC.

3.3. Under transient conditions, MODFLOW model evaluation

Table 2 summarizes MODFLOW model performance in simulating daily baseflow using three statistical metrics such as Nash–Sutcliffe Efficiency (NSE), root mean squared error to standard deviation ratio (RSR), and percent bias (PBIAS). These three statistical metrics are recommended to be simultaneously utilized for evaluating and rating hydrological model performance (Ritter & Munoz-Carpena 2013). Table 2 shows that the model's performance was generally satisfactory, with an average NSE of 0.65, RSRS of 0.59, and PBIAS of 4.24% for both the calibration and validation periods (Table 2). The overall performance of the model is rated as satisfactory (Waseem *et al.* 2017). We also considered other goodness-of-fit statistics, (r), and mean bias error (MBE) that are widely used to evaluate the hydrologic model performance and to describe the degree of collinearity between simulated and observed data. Due to r and MBE values respectively, greater than 0.5 and close to 0, the MODFLOW model likewise produced results that may be considered acceptable (Dangol *et al.* 2022).

The MODFLOW model adequately captured the trends of the observed hydrograph, as seen by the comparison of the simulated and observed daily baseflow for the Heeia aquifer at the Haiku and Wetland outlets (Figure 7). In addition, the model was calibrated based on 2 years of observed groundwater levels at the Heeia stream diversion piezometer and piezometer of the Heeia weather station within the Wetland (see Figure 3 for the piezometer locations). The green calibration targets next to the different timesteps were used to match computed values with the observed values (Figure 8). The computed groundwater levels are within the green range (targeted values) as shown in Figure 8.

3.4. FSGD evaluation in various transient-state scenarios

Particularly during the dry season, the daily FSGD was quite sensitive to sea level increase (Figure 9). By the end of the century, when SLR equals 1.1 mt. The FSGD magnitude will have decreased by roughly 10% compared to the middle century (SLR = 0.4 m). On the other hand, according to an earlier study, a rise in sea level will increase the recirculated underwater groundwater output (Gonneea *et al.* 2013). Another scenario examined how the restoration of the Heeia wetland, projected CC, and SLR at the end of the century might affect FSGD fluxes (Figure 10). Wetland restoration, CC (RCP8.5), and combination change would all have negative effects on FSGD during the wet season that are, respectively, 1, 9, and 15%. The relative changes were, however, 2, 13, and 46% during the dry season. The fact that only 7% of the entire watershed has been restored is probably to blame for the wetland restoration's weak impact. FSGD's negative impact value is greatest during the dry season. Even though the magnitude of FSGD decreased over time, it continued to deliver between 1.5 and 3.5 times more fresh water to Kaneohe Bay than the Heeia streamflow (Figure 11). In general, the flux of FSGD to the coastal ocean was anticipated to be significant due to enhanced recharge rate, porous basalt with high hydraulic conductivity, and steep seaward hydraulic gradient in the shallow unconfined coastal aquifer, particularly on the windward side of Oahu Island (Dulai *et al.* 2016b). According to the findings, which were in line with those of other studies, the FSGD was regarded as a significant supply of freshwater for the windward side of Oahu's coastline (Dulai *et al.* 2016a). The groundwater levels rose as a result of the increased recharge rate, which in turn caused an increase in the hydraulic gradient, particularly in steep topography like the Heeia watershed, which in turn forced an increase in the FSGD fluxes (Lau & Mink 2006). The findings showed that the FSGD and baseflow had reasonable correlations ($r^2 \geq 0.5$) (Figure 12). However, before entering the wetland, the groundwater head at the Heeia diversion piezometer and FSGD flows displayed a substantial exponential regression connection (Figure 13). With R^2, the coefficient of determination, of 95%. This function illustrated the significant correlation between groundwater head and FSGD flows. Depending on the observed head in

Table 2 | Statistical outcomes for calibration and validation for the daily baseflow simulation over several periods

Simulation	Station	Period	Time span	NSE	RSR	PBIAS (%)	RMSE (m^3/s)	MBE (m^3/s)	r
Pre-development	Haiku	Calibration	1950–1959	0.74	0.51	−1.172	0.01	0.00033	0.86
	Wetland	Calibration	1950–1959	0.62	0.62	2.814	0.01	0.00604	0.81
Post-development	Haiku	Validation	2005–2014	0.56	0.66	−5.228	0.01	−0.00365	0.87
	Wetland	Validation	2005–2014	0.68	0.56	7.928	0.01	0.00614	0.92

NSE, Nash–Sutcliff efficiency; RSR, root mean squared error to observation standard deviation; PBIAS, percent bias; RMSE, root mean squared error; r, correlation coefficient; MBE, mean bias error.

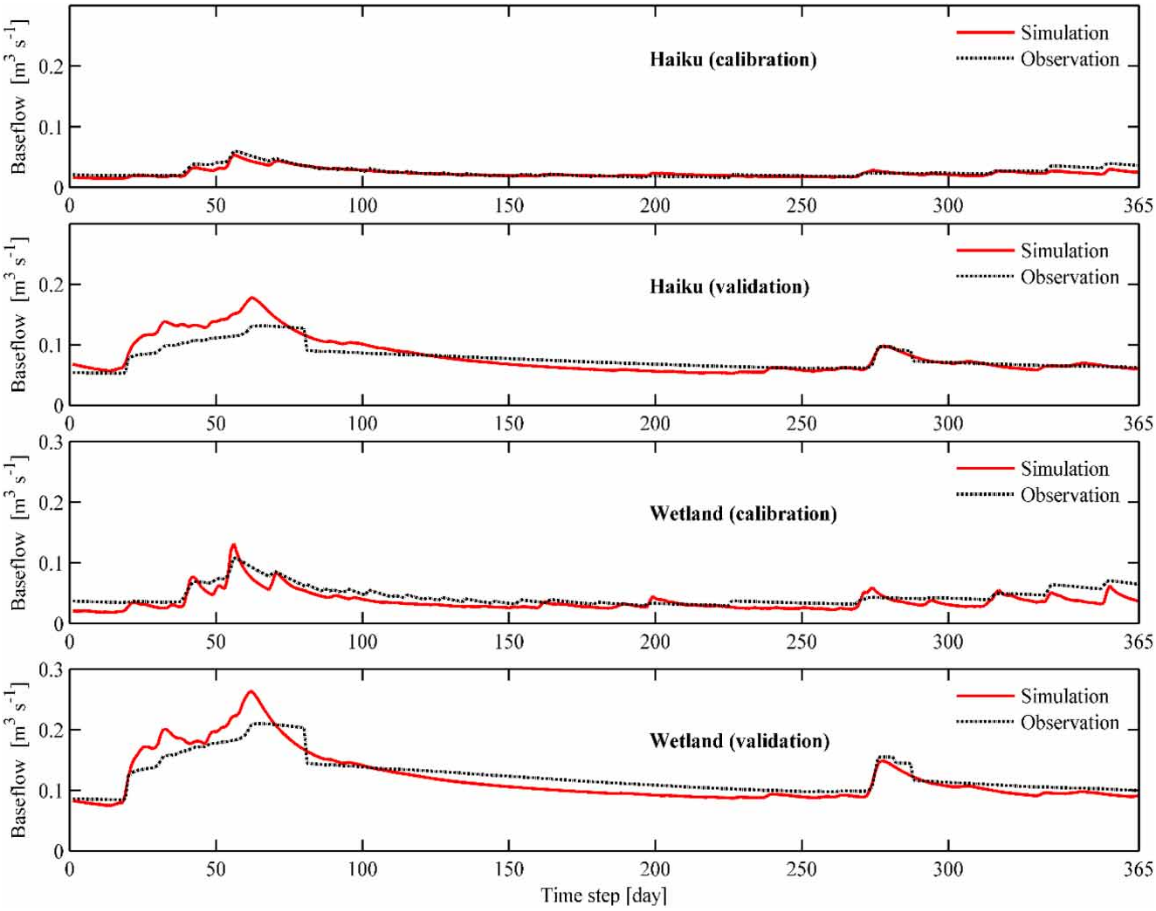

Figure 7 | The baseflow at the stations in Haiku and Wetland over a year, as simulated and observed. For calibration and validation, respectively, the years 1951 and 2006 were employed.

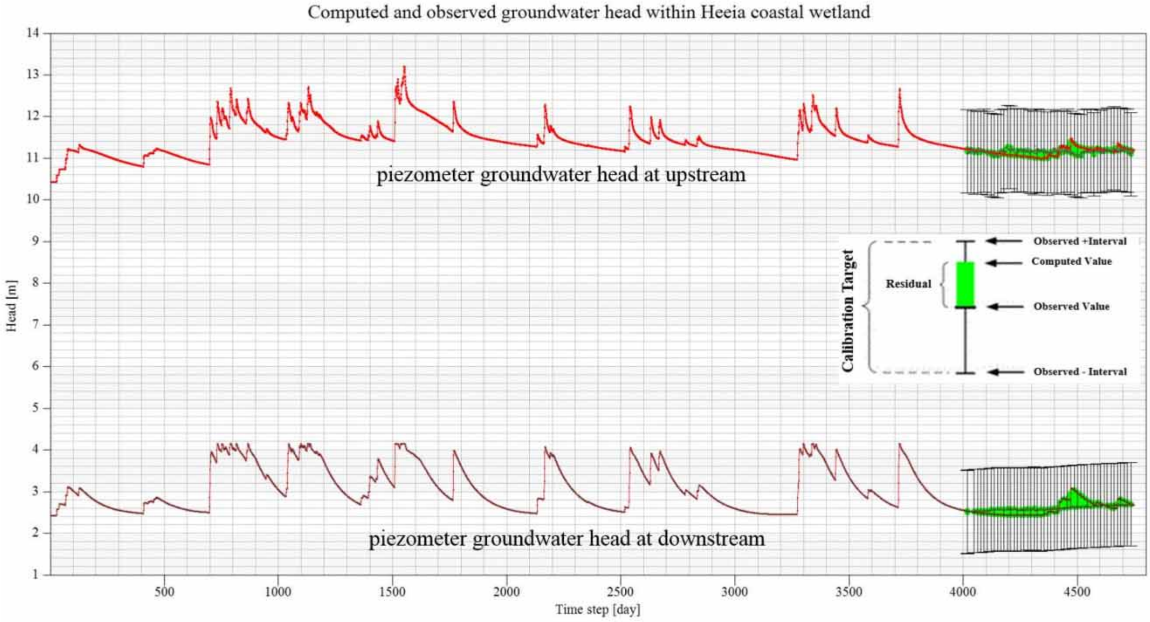

Figure 8 | The post-development period's various timesteps' measured and computed groundwater levels.

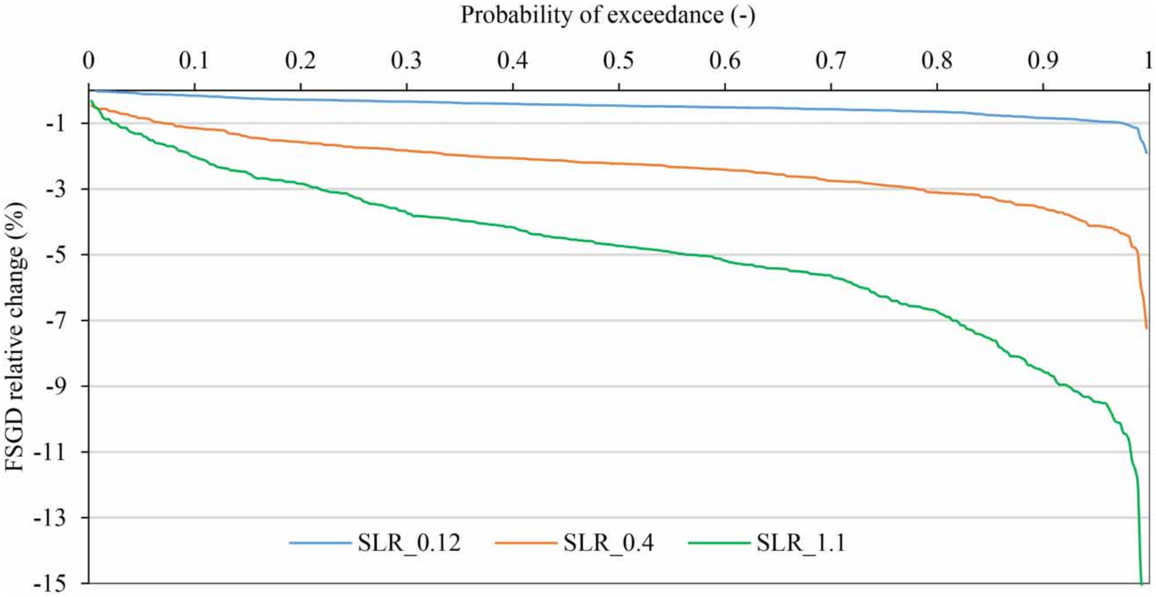

Figure 9 | Daily percentage change in the FSGD caused by the rise in sea level.

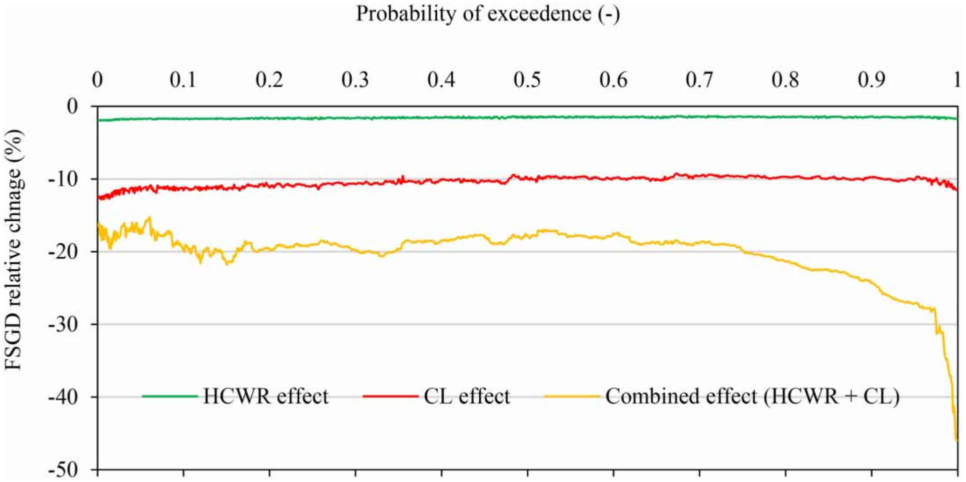

Figure 10 | Under several scenarios of HCWR, CC, and SLR, the daily relative percent change in the FSGD duration curve.

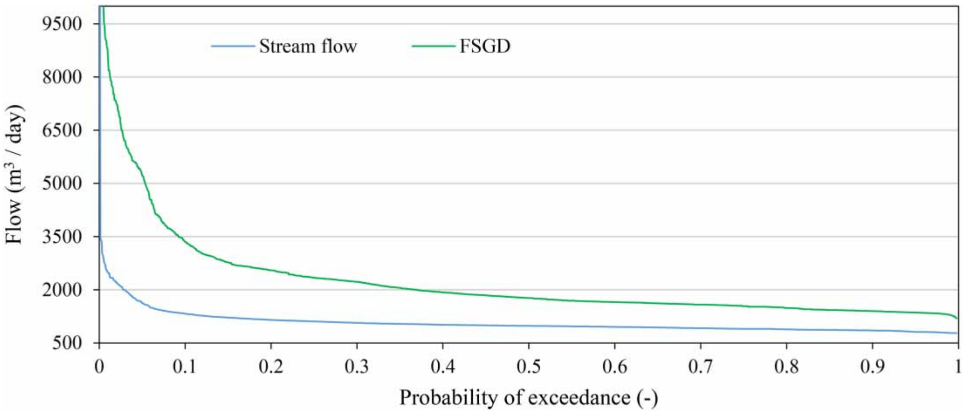

Figure 11 | Comparison of the Heeia streamflow estuary and the FSGD flow duration curve across the coastal shoreline.

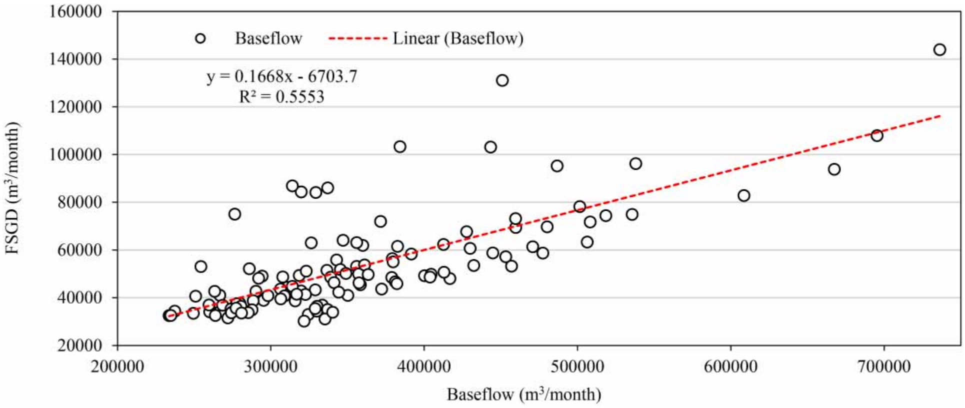

Figure 12 | The connection between FSGD fluxes along the Heeia Coastal Shoreline and monthly groundwater discharge (baseflow).

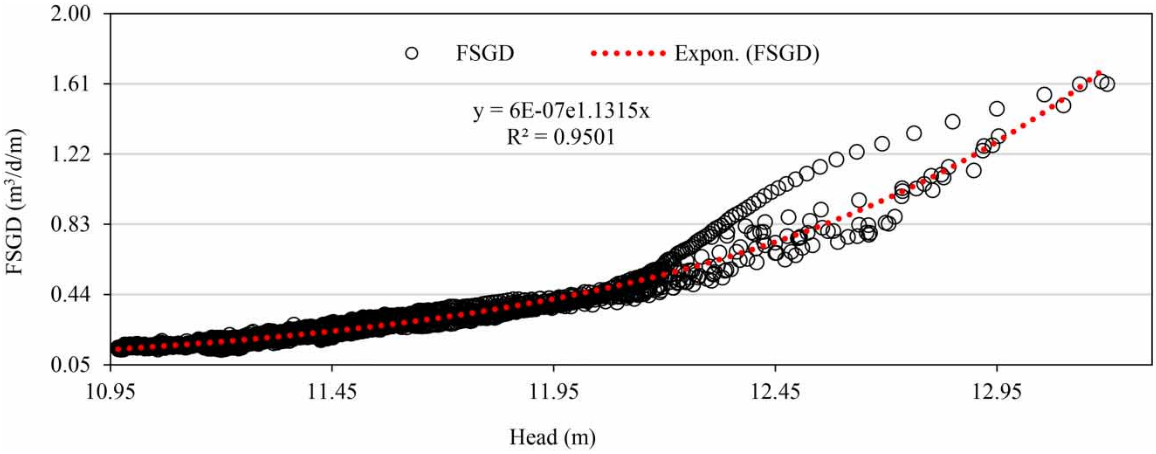

Figure 13 | The connection between FSGD flows along the Heeia Coastal Shoreline and the head of the coastal aquifer.

coastal wetlands, the exponential function can be utilized as a method to estimate FSGD fluxes for the temporal scale under transient conditions.

4. CONCLUSIONS

This study evaluated the FSGD fluxes along the Heeia Coastal Shoreline using integrated hydrological modeling. The tools for FSGD assessment used the calibrated and verified MODFLOW model under transient and steady-state settings with SWAT model outputs for recharge. Within the Heeia watershed, the MODFLOW model was created to represent the groundwater system of a shallow unconfined aquifer. Based on filtered baseflow at Haiku streamflow and virtual wetland stations as well as observed groundwater head within the Heeia watershed, the model was calibrated and validated. Under limited conditions of hydrological data, the MODFLOW model accurately captured the groundwater head and discharge of a shallow, unconfined coastal aquifer with acceptable performance and satisfying statistical assessment values. The results demonstrated that FSGD was considerably influenced by anthropogenic influences, recharge rate, and CC impact under steady-state settings, particularly near the end of the 21st century. Due to a significant 33% decrease in recharge and an increase in groundwater withdrawals, the average decline in FSGD flux from the pre-development to the post-development period would be roughly 53%. Additionally, it is anticipated that the average FSGD fluxes will decline by 0.3, 2, and 10%, respectively, as a result of the HCWR effect, the CC impact, and the combined wetland restoration, CC, and SLR (1.1 m) effect. The results demonstrated that the FSGD was considerably impacted by the effects of CC, SLR, groundwater head at the coastal aquifer, and recharge rate under transient conditions, particularly by the end of the 21st century. The respective average annual decline in FSGD fluxes during the scenarios of sea level m for the near century effect was 0.5, 2, and 5% due to increasing the sea level by 0.12 m for the near century and 0.4 m for the middle century and 1.1 m for the end century. In the scenarios with wetland restoration, CC, and combined wetland restoration, CC, and SLR (1.1 m) effects, the average drop in FSGD fluxes was 1.6, 10, and 20%, respectively. FSGD fluxes during post-development were, according to the research, 1.5–3.5 times greater than the total flow of freshwater provided to Kaneohe Bay by the Heeia stream. Additionally, recharge, SLR, and groundwater withdrawals during the dry season had a greater impact on FSGD fluxes than during the wet season. Due to the low percentage of recharge to rainfall ratio, particularly at the highest exceedance likelihood, it was discovered that the percent of FSGD to recharge was low during the wet season but high during the dry season. The results also showed that baseflow and FSGD had reasonable relationships. On the other hand, for the coastal unconfined aquifer, the FSGD displayed a large exponential connection with the groundwater head. The relationship between groundwater head and coastal wetlands could be used as a method to continually assess FSGD.

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AUTHOR CONTRIBUTIONS

K.A.G. and O.T.L. conceived, designed, performed, analyzed, interpreted, and drafted the paper. H.D. conceived and supervised the research, contributed ideas during analysis, and edited the paper.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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